WSRC-RP-2001-00171
Rev. 0

Summary and Status of DNAPL Characterization and ${f I}$	Remediation
Activities in the A/M Area, Savannah River Site	

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Prepared for the United States Department of Energy under Contract No. DE-AC09-96-SR18500

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## Summary and Status of DNAPL Characterization and Remediation Activities in the A/M-Area, Savannah River Site

November 2000

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#### Abbreviations and Acronyms

CPT cone penetrometer

DHEC Department of Health and Environmental Control

DNAPL dense non-aqueous phase liquid DUS Dynamic Underground Stripping

FY fiscal year

GPR ground penetrating radar HPO Hydrous Pyrolysis Oxidation

H<sub>2</sub>O water

NAPL non-aqueous phase liquid nd below detection limit PCE tetrachloroethylene PITT Partitioning Tracer Tests

PVC polyvinyl chloride

RCRA Resource Conservation and Recovery Act

RF radio frequency
SC South Carolina
SRS Savannah River Site
SVE Soil Vapor Extraction
TA Temporary Authorization
1,1,1-TCA 1,1,1-trichloroethane
TCE trichloroethylene

bgs below ground surface feet mean sea level

Kg kilogram lbs pounds

ppb parts per billion

ppbv parts per billion volume ppmw parts per million weight µg/g micrograms per gram

#### **EXECUTIVE SUMMARY**

Characterizing and developing clean-up plans for residual undissolved industrial solvents, also known as dense non-aqueous phase liquids (DNAPLs), in the soil and groundwater beneath former "source areas" are key elements in the overall groundwater corrective action for the A/M-Area of the Savannah River Site (SRS). These activities support the goals of the A/M-Area Resource Conservation and Recovery Act (RCRA) permit. Based on ten years of data, SRS developed the A/M-Area DNAPL Strategy flowchart that lays out DNAPL characterization and clean-up activities in a logical and organized fashion. The flow chart consists of several steps – identification of suspect source areas, confirmation of the DNAPL status (presence or absence), delineation of location and quantity, and identification/permitting of clean-up activities. An important feature of the flow chart is that it is integrated with other activities within the corrective action. Completion of DNAPL related work does not signify that a site is clean, rather that the DNAPL source has been appropriately addressed and the remainder of the A/M-Area technology portfolio addresses remaining groundwater, vapor phase, or sorbed contamination. Removing pure phase DNAPL, to the extent possible, is a critical step in the A/M-Area solution. This step allows the other clean-up activities to work on suitable concentration levels and for a shorter time frame – a time frame that is less controlled by the slow dissolution of a large reserve of DNAPL.

SRS identified 16 possible or confirmed DNAPL source areas in the A/M-Area. We apply the general flowchart approach to each suspect area. One of these areas, notably the 321M Solvent Storage Tank, has been confirmed and is in the full-scale cleanup stage. Other suspect or confirmed DNAPL source areas (miscellaneous leakage from various former process buildings and the like) are in the confirmation, rapid response and/or characterization stages as noted below. A few of the DNAPL sources (e.g., M-Area Basin and its upstream Process Sewer, and the A-014 Outfall) have been confirmed and are being remediated by rapid response actions such as soil vapor extraction (SVE) or DNAPL removal/destruction pilot studies. These rapid responses have been implemented under RCRA while characterization efforts continue to delineate the DNAPL quantity, location and geometry and to develop a more complete DNAPL targeted solution. Based on the low concentrations observed in the data collected to date, a few potential sources are now being addressed under the general A/M-Area RCRA corrective action without additional planned DNAPL activities (e.g., the Upper 700 Area Building 703-A and the M-Area process sewer leading to the A-014 Outfall). This report summarizes historical A/M-Area DNAPL activities and data, and presents the overall A/M-Area strategy flowchart, the status work for each DNAPL source zone (or potential source zone), and future A/M-Area DNAPL plans.

#### 1.0 INTRODUCTION

Metals fabrication and related industrial operations within the A/M-Area of the Savannah River Site (SRS) resulted in the releases of over 1.6x10<sup>6</sup> Kg (3.5x10<sup>6</sup> pounds) of chlorinated solvents, primarily trichloroethylene (TCE) and tetrachloroethylene (PCE) into the subsurface. These wastes were discharged over the period from approximately 1955 through 1980. The releases have resulted in the contamination of the vadose zone (the upper 45 m, or approximately 135 ft, of interbedded sands and clays) underlying and adjacent to the disposal areas, as well as shallow groundwater over an area of approximately 5 km². The groundwater contamination was identified in 1980 and remediation strategies were rapidly developed and implemented for both the dissolved plume and contaminated soil vapor. During characterization activities in 1991, the presence of dense non-aqueous phase liquid (DNAPL) was confirmed by visual examination of liquid samples that were recovered with a bottom-filling bailer from groundwater monitoring wells. An active program to address DNAPL was initiated. The program has identified the strengths and weaknesses of various DNAPL technologies and DNAPL management approaches.

At large industrial sites like the A/M-Area, undissolved DNAPL in soil and groundwater is the most significant barrier to successful cleanup. DNAPL acts as a reservoir, generating contaminant levels above remediation concentration goals for an extended time period. Technical and operations personnel at SRS have developed and tested a variety of DNAPL characterization and remediation methods over the past ten years. We have refined the DNAPL strategy during this period based on the results of the various tests. The current SRS DNAPL strategy is documented in the form of a flow chart that defines our approach to DNAPL management. Importantly, the DNAPL strategy is integrated into the RCRA groundwater corrective action and is being developed within the context of an overall plan for clean up of this area. This allows us to select characterization and clean-up methods that are appropriate to character and distribution of the various zones within the contaminant plume (source zones, primary dissolved plume, and dilute fringe).

The DNAPL strategy that has evolved addresses the A/M-Area source zone(s). The strategy emphasizes detailed depth-discrete delineation of subsurface DNAPL to optimize remediation. This is particularly critical for DNAPL treatment technologies such as enhanced mobilization (e.g., using steam, cosolvents or surfactants) and in situ destruction methods (e.g., permanganate or Fenton's reagent) because the treatment costs are a strong function of target treatment volume (i.e., unit costs are \$ per volume of soil treated). A sequence of complementary low cost characterization methods ("toolbox") is used for the characterization activities. The resulting approach, similar to exploration geochemistry, maximizes information to refine the conceptual model of target DNAPL at a minimum cost. A second key feature of the strategy is that DNAPL treatment methods are categorized based on cost, logistics and aggressiveness. We developed criteria, principally DNAPL mass and the treatment zone volume to assist in selecting the best technology for each discrete area of DNAPL accumulation. Large quantities of DNAPL are addressed with the most aggressive (i.e., expensive) methods; smaller quantities are

addressed with less expensive methods. We also identified rapid response options for areas where DNAPL related modifications to existing operations/infrastructure are feasible. A final key feature of the strategy was development of criteria for identifying that a suspect DNAPL area does not have sufficient contamination to justify a DNAPL specific remediation – for these areas, the ongoing and planned future operation of the groundwater treatment system is the most appropriate action.

## 2.0 CONCEPTUAL MODEL OF DNAPL BEHAVIOR IN COASTAL PLAIN SEDIMENTS

Review of the literature regarding subsurface DNAPL migration and knowledge of soil physics led to the development of a conceptual model of DNAPL migration in the subsurface in A/M-Area (Jackson et al., 1996). As the DNAPL migrates in the subsurface, local heterogeneities of the sediments influence DNAPL movement and accumulation. DNAPL continues to migrate given a sufficient driving force in the form of continued disposal of solvent wastes. When the DNAPL source is exhausted and the driving force for movement removed, the DNAPL mass in the subsurface will reach a stable configuration based upon the applied gravitational, hydrodynamic, and capillary forces. At this stage, residual DNAPL remains in the pore throats along the migration path and in accumulation areas determined by geological structure. In the vadose zone, the DNAPL is often the wetting phase, and thus, residual DNAPL is held by capillary forces in the pores of layered fine-grained sediments typical of the Atlantic Coastal Plain. Below the water table, DNAPL tends to move vertically in narrow "fingers" and then accumulate in thin laterally extensive layers at the base of the affected aquifer. In contrast to the vadose zone, DNAPL accumulation below the water table is in coarsegrained sediments immediately above clayey intervals. After the source is removed, residual DNAPL is left throughout the entire migration pathway due to "snap-off" in pore throats as the DNAPL front moves away. Because of the relatively low solubility of DNAPL solvents, all of these types of residual and accumulated source material in the subsurface represent a large fraction of the original mass released at most sites. As a result, the DNAPL represents the primary long-term source for groundwater contamination over an extended period (circa 100s of years). (Jackson et al., 1996).

Current conceptual models indicate DNAPL will penetrate down into the water table when it has a high application rate over a small area. In these cases, the DNAPL obtains a large enough continuous (organic phase) head to penetrate the capillary fringe. Once the capillary fringe is penetrated the DNAPL flow is primarily controlled by the structure of any capillary barriers (clays and the like).

#### 3.0 STATUS OF OVERALL A/M-AREA CORRECTIVE ACTION

Results of early work identified that approximately 3.5 million pounds of chlorinated solvents had been spilled or disposed through process sewers to the surface/subsurface in A/M-Area. This contamination has been addressed through the RCRA permit for A/M-Area (specifically related to the M-Area Settling Basin and Vicinity) and the RCRA postclosure requirements (defined in the A/M-Area Groundwater Corrective Action). In the 1980's and 1990's this has led to the:

- a) closure of the M-Area Settling Basin through stabilization and the placement of a RCRA style cap,
- b) operation of two full-scale groundwater pump-and-treat systems in the central A/M-Area and in the northern sector,
- c) targeted air sparging, bioremediation, soil heating and oxidation remediations,
- d) installation of in-well vapor stripping (recirculation well) systems to reduce the migration of the primary plume into the low concentration area in the southern sector,
- e) installation of full-scale soil vapor extraction systems throughout the area from 1987 through 1995, and
- f) operation of Dynamic Underground Stripping and Hydrous Pyrolysis (steam based) treatment in the soil and shallow groundwater underlying the former solvent storage tank.
- g) Installation and operation of passive SVE (using barometric pumping and the BaroBall<sup>TM</sup> device) at the Metallurgical Laboratory and other lower concentration vadose zone sites.

These various systems have removed more than 1 million pounds (approximately 450,000 Kg) of chlorinated solvent from the soil and groundwater to date.

Much of the recent effort in the overall A/M-Area program addresses two portions of the plume, the source (DNAPL) areas and the low concentration (distal) areas. Contaminant conditions in these areas are not well suited to traditional treatments such as pump-and-treat. This process of matching the nature of the characterization treatment to the nature of the contaminant plume in various parts of the overall A/M-Area plume has been well documented (Looney, 2000; Harris *et al.*, 2000). The approach has now been adopted for environmental restoration projects across SRS (each area publishes their groundwater strategy using this paradigm). In A/M-Area, the DNAPL strategy has been formalized to address technical issues of characterization and clean-up within the context of the overall corrective action. In the distal area, natural and sustainable methods that are consistent with the low concentrations are being evaluated.

#### 4.0 STATUS OF A/M-AREA DNAPL ACTIVITIES

As part of the A/M-Area groundwater corrective action, SRS has actively identified facilities that may have contributed DNAPL to the subsurface during their operations, characterized the most significant potential sources, and initiated DNAPL targeted cleanup actions based on the data. The technical and management approach to A/M-Area DNAPL has now been formalized into a flowchart (submitted in the 2000 RCRA permit application) to clarify how the work is planned and carried out and to facilitate tracking of progress for each of the identified potential DNAPL sources. The flowchart defines the types of activities performed for each area and the basis for decision-making as the project moves through the various stages (screening, characterization, possible DNAPL specific clean-up, etc.). The identified potential sources were classified into three groups depending on the type of expected release scenario. The groups are storage areas (spills and leaks), use areas (spills and leaks) and disposal areas (documented as part of operations and often high volume releases). The suspect and confirmed DNAPL sources (Figure 4.1) that are currently being addressed by the A/M-Area groundwater corrective action include (letter designations on the map are the same as those used in Marine and Bledsoe, 1984):

#### STORAGE AREAS

321-M Solvent Storage Tank (shown as "C" on map) Rail Storage East of Building 313-M (shown as "A") Drum Loading South of Building 313-M (shown as "E") 713-A, Central Storage Facility

#### **USE AREAS**

Buildings 313-M (Slug Manufacturing Facility), 320-M (Target Manufacturing Facility) and 321-M (Fuel Manufacturing Facility)

Building 305-A

Building 773-A (SRTC)

Upper 700 Area

Lower 700 Area

#### SOLVENT DISPOSAL AREAS

M-Area Settling Basin Process Sewer (to M-Area Settling Basin) (shown as "F")

M-Area Settling Basin (shown as "D")

M-Area Process Sewer (to A-014 outfall)

A-014 Outfall

Swampy Area on which Building 321-M now sits (shown as "B")

As the conceptual model implies, detecting the DNAPL zones in the subsurface is challenging. Improved characterization tools have been and continue to be used to allow for quicker, cheaper, more accurate characterization of the subsurface. DNAPL characterization activities began in 1992 with the ultimate goal to enable more precise targeting of DNAPL remediation efforts (Looney et al., 1992). The A/M-Area DNAPL

flowchart is based on the results of the targeted characterization (see Cohen et al, 1993) and clean-up activities to date. Past characterization results have been documented in a series of reports and results for FY00 are summarized below. This is followed by an overview of the DNAPL results from all years, a description of the logic and details of the generic A/M-Area DNAPL flowchart and specific annotated flowcharts summarizing the status for each of the potential DNAPL source areas/groups.

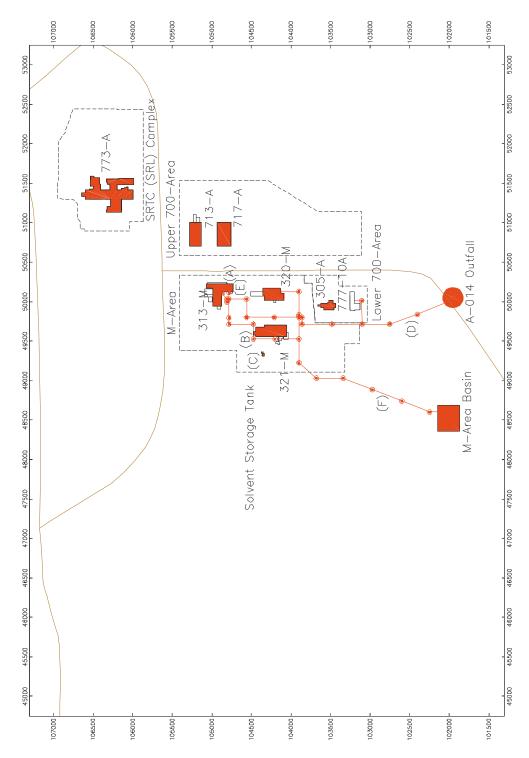


Figure 4.1 Base Map Showing A/M-Area and the Location of Suspect, or Confirmed, DNAPL Sources

#### 5.0 CHARACTERIZATION ACTIVITIES AND DATA

#### 5.1 Historical Information through FY 96

Historical A/M-Area data related to DNAPL is reported and interpreted in several technical reports and in the RCRA permit and related documents. The primary topical references from this period are Assessing DNAPL Contamination, A/M-Area, Savannah River Site: Phase I Results (Looney et al., 1992) and Estimating the Thickness of DNAPL within the A/M-Area of the Savannah River Site (Jackson et al., 1996). These reports discuss and present available information and the DNAPL implications and interpretation. In the 1992 report, Looney et al., reviewed process use and evaluated previous monitoring well data and soil core data with regard to potential DNAPL target areas. The investigators also performed a variety of screening activities, including, geophysical and caliper logs in existing wells, detailed analysis of collected DNAPL phases, a structure contour evaluation of the green clay, and additional activities. Important data generated for the report included a cone penetrometer study of lithology in the vicinity of the M-Area Settling Basin. The report also relied on sediment concentrations and vertical cross sections previously generated by Gordon et al. (1982), Marine and Bledsoe (1984), Pickett (1985) and the RCRA Part B permit. The 1996 report significantly extended this evaluation using a detailed time trend analysis for each monitoring well in the vicinity of potential DNAPL sources, additional interpretation related to the structure of critical clay layers in the vicinity of these sources, and a mathematical analysis of potential migration pathways. The two reports clarified the nature and distribution of DNAPL near the M-Area Settling Basin (the largest A/M-Area source) and provided indications of DNAPL behavior near the A-014 Outfall and other suspect areas. Based on the information, three pilot scale DNAPL targeted treatments were deployed. These included six phase heating and radiofrequency heating along the former process sewer line near the settling basin, and in situ oxidation using Fenton's reagent in a DNAPL accumulation zone west of the M-Area Settling Basin. As discussed below, the pre-test and post-test data from these activities provide additional information related to DNAPL behavior and distribution.

#### 5.2 FY97 through FY99

Specific follow-on characterization activities were conducted in FY97 through FY99 to refine our knowledge of the extent of the VOC plume and the spatial distribution of DNAPL within the plume. The following activities were conducted and the documents in which the results were reported are listed below.

Characterization of the Vadose Zone at the A-014 Outfall using CPT based technologies as reported in "Characterization Activities to Determine the Extent of DNAPL in the Vadose Zone at the A-014 Outfall of A/M-Area (U), WSRC-RP-99-00569.

Characterization of a potential DNAPL transport pathway before and after a demonstration of a DNAPL remediation technology using rotosonic drilling as reported

in "Final Report for Demonstration of In Situ Oxidation of DNAPL Using Geo-Cleanse Technology (U)", WSRC-TR-97-00283.

Characterization below the water table at known DNAPL source areas using rotosonic drilling to complete 13 soil borings with soil plug samples as reported in "A/M-Area DNAPL Characterization Report for Cores Collected in FY97 and 1Q98 and 2Q98 (U)", WSRC-TR-98-00296.

Characterization adjacent to and below the M-Area Settling Basin using rotosonic vertical and angle drilling to determine the spatial distribution of DNAPL adjacent to and below the basin as report in "A/M-Area DNAPL Characterization Report for Cores Collected in 2Q99", WSRC-TR-99-00468.

#### 5.3 FY00

Characterization activities in FY00 included depth discrete soil sampling of borings drilled using the rotosonic method, soil gas samples and lithology data gathered using cone penetrometer techniques. The depth discrete soil samples were collected adjacent and below the M-Area Settling Basin and adjacent to the A-014 outfall. The sampling locations are shown on Figure 5.1 and the results are summarized in Table 5.1. Depth discrete soil samples were also collected in FY00 to support the Lynntech demonstration and the Dynamic Underground Stripping (DUS) deployment. The results of those sampling events are reported in separate documents authored by Vangelas (2000b and 2000a, respectively).

Depth discrete soil borings were collected at 5 locations using the rotosonic drilling method during the months of March and April 2000. The core descriptions/geophysical logs and daily activity logs for these borings are included in Appendices A and B. The drilling activities occurred at the M-Area Settling Basin and the A-014 Outfall. At the M-Area Settling Basin one vertical boring was drilled adjacent to the western corner of the basin and one angle boring was drilled from the western corner of the basin towards the center of the basin. At the A-014 outfall two angle borings were drilled running parallel to the outfall stream. A third boring was drilled vertically above the location where PCE concentrations identified in one angle boring indicated the presence of DNAPL. All borings were sampled from surface to the top of the Green Clay.

The sampling to support the Lynntech demonstration Vangelas *et al.* (2000b).involved collecting soil samples using a Geo-Probe after the Lynntech soil ozone treatment demonstration was completed. The purpose was to determine the amount of PCE and TCE remaining in the soil to allow the Lynntech personnel to evaluate the effectiveness of the ozone in the destruction of DNAPL. This demonstration was conducted adjacent to the 321-M Solvent Storage Tank concrete pad. The sampling was conducted in March 2000. Three post-test soil borings were collected in the treatment cell, a 15 foot radial area. Sediment samples were collected from 340 ft msl to 330 ft msl (30 ft to 40 ft bgs). Of the 57 samples collected none contained TCE at DNAPL levels (>  $200 \mu g/g$ ) while 2 samples (3.5 %) contained PCE at DNAPL levels (>  $50 \mu g/g$ ).

The sampling to support the DUS deployment Vangelas *et al.* (2000a).involved collecting soil samples at 4 locations from mud rotary drilled soil borings. The purpose of this sampling was to provide additional data to the primary vendor on the pre-deployment soil conditions. Soil plug samples were collected from surface to the top of the Green Clay at approximately 20 foot intervals. Of the 98 samples collected none contained TCE at DNAPL levels (> 200  $\mu$ g/g) while 2 samples (2%) contained PCE at DNAPL levels (> 50  $\mu$ g/g). The samples containing the PCE at DNAPL levels were located at elevations of 350 ft msl (20 ft bgs) and 349 ft msl (21 ft bgs).

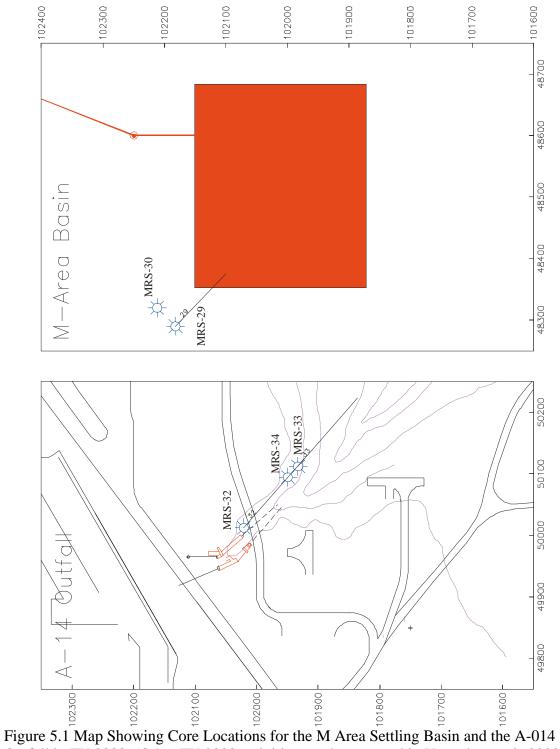


Figure 5.1 Map Showing Core Locations for the M Area Settling Basin and the A-014 Outfall in FY 2000 (Other FY 2000 activities are documented in Vangelas *et al.*, 2000a and 2000b)

Table 5.1. Identification of Elevations at which DNAPL and suspect DNAPL concentrations were reported for borings from the FY00 DNAPL investigations at the M-Area Basin

Elevation	MRS29	MRS30
343-307	nd	nd
307-305		nd
305-229 (231 H <sub>2</sub> O table)	nd	nd
228		
227		nd
226-225		
224		
223		
222		
221-220		
219-216		
215		
214-213		
212	SD	
211-210		
209-208	SD	
207		SD
206	SD	
205		
204		
203		
202-201	SD	
200		SD
199-197		
196		SD
195		
194		Total Depth
193		
192		
191		
190		

D – DNAPL concentrations ( $45\mu g/g$  PCE or greater), SD – suspect DNAPL concentrations (between ½ the DNAPL concentration and the DNAPL concentration,  $22.5 \mu g/g < x < 45 \mu g/g$ ). nd – below detection limit of  $0.001\mu g/g$ . Clear blocks indicate concentrations between suspect DNAPL and below detection. Shaded blocks indicate no samples collected at those elevations. H<sub>2</sub>O table elevations based on information from GIMS database.

Table 5.2. Identification of Elevations at which DNAPL and suspect DNAPL concentrations were reported for borings from the FY00 DNAPL investigations at A-014 Outfall

Elevation	MRS32	MRS33	MRS34
353 352 – 348			
347			
346 –345			
344			
343 – 341			
340	nd		Land Surface
339		Land surface	nd
338		nd	
337			
336	nd		
335			
334			
333	nd		nd
332			
331			
330			nd
329	nd		
328			
327			
326			
325			
324			
323		nd	
322			
321			
320			
319		nd	
318			
317			
316			
315			
314			
313			
312		nd	
311			
310			
309			
308			
307			
306			
305		nd	

Elevation	MRS32	MRS33	MRS34
304 – 303	WINDSA	IVIIXOU	+CC/IIVI
302			
301			
300			
299			
298 –296			
295			
294			
293 –291			
290			
289			
288			
287			
286			
285		nd	
284			nd
283			
282			
281			
280 – 278			
277			
276			nd
275			IIQ
274			
			1
273			nd
272			
271			
270			
269	nd		
268			
267			
266			
265			
264 - 263			
262	nd		nd
261			
260	nd		
259			
258			
257			
256			nd
255			IIQ
254			
			nd
253			nd
252	]		

Elevation	MRS32	MRS33	MRS34
251		nd	
250			
249	D		
248	D		
247			nd
246			
245			
244	_		
243	_		
242			
241			
240			
239			
238			
237			
236			
235			
234			
233		nd	
232 (H <sub>2</sub> O table)	_	Tig.	
231			
230			
229			
228			
227 – 226			
225			
224			
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Elevation	MRS32	MRS33	MRS34
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198			Total Depth
197 – 196			
195			

D-DNAPL concentrations (45µg/g PCE or greater), SD – suspect DNAPL concentrations (between ½ the DNAPL concentration and the DNAPL concentration, 22.5 µg/g < x < 45 µg/g). nd – below detection limit of 0.001µg/g. Clear blocks indicate concentrations between suspect DNAPL and below detection. Shaded blocks indicate no samples collected at those elevations.  $H_2O$  table elevations based on information from GIMS database.

#### 6.0 PRESENTATION OF CUMULATIVE A/M-AREA DNAPL DATA

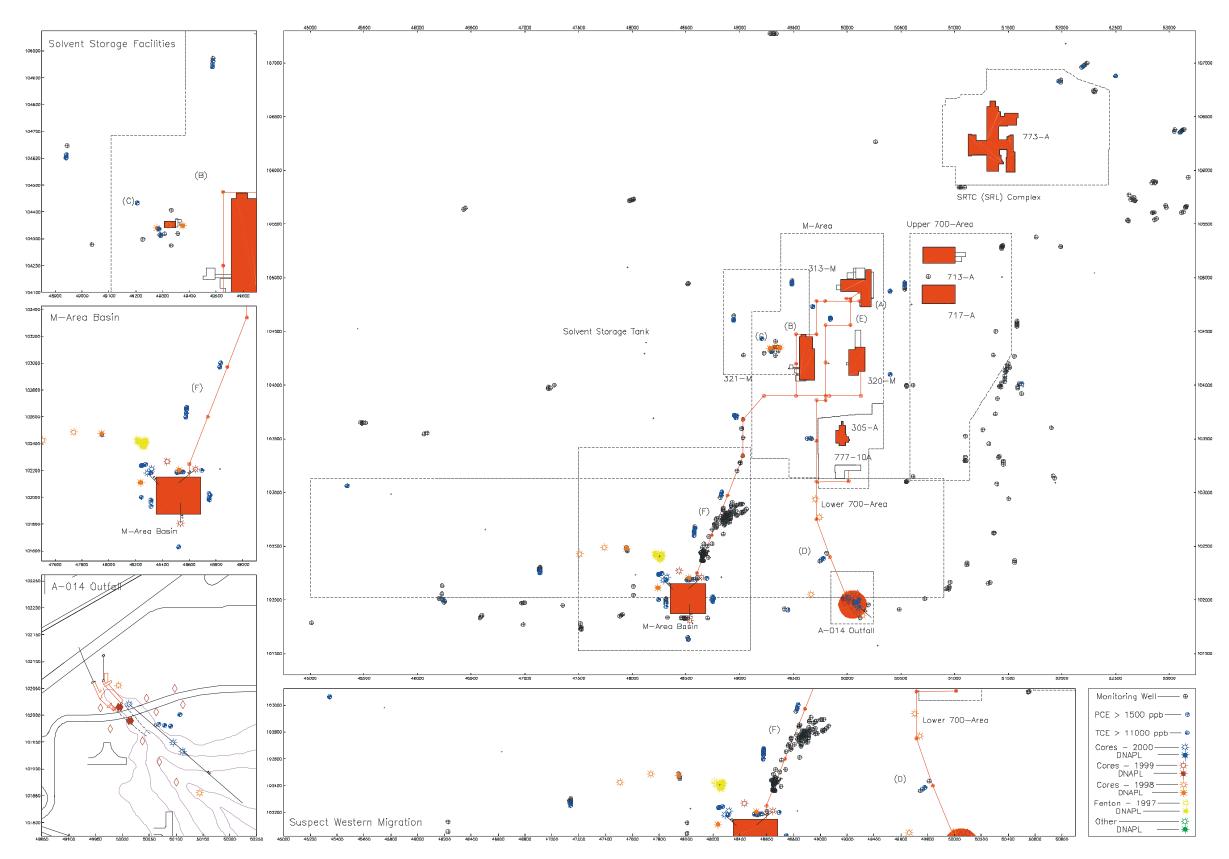
The available data for the various DNAPL related studies has been assembled onto a map with symbols and colors that denote the different sample types and DNAPL relevant concentration ranges, respectively. This map is provided in Figure 6.1.



{see 11" x 17" insert sheet}

Figure 6.1 Summary of Cumulative DNAPL related Characterization Data from the A/M-Area, Savannah River Site

WSRC-RP-2001-00171 Figure 6.1 11" x 17" insert between pages 18 & 19



#### 7.0 DNAPL STRATEGY - A/M-AREA CORRECTIVE ACTION

#### 7.1 Overall A/M-Area DNAPL Characterization and Remediation Flowchart

In 1991, the presence of DNAPL in A/M-Area was confirmed by visual examination of liquid samples that were recovered with a bottom-filling bailer from monitoring wells MSB 3D and MSB 22. An active program to address DNAPL was initiated. The program has identified the strengths and weaknesses of various DNAPL technologies and DNAPL management approaches. The data collected since 1991 document that residual DNAPL in soil and groundwater is the most significant barrier to successful completing cleanup of large industrial sites like the A/M-Area. DNAPL acts as a reservoir, generating contaminant levels above remediation concentration goals for an extensive time period, thus prolonging clean up. During this period, SRS developed and tested a variety of DNAPL characterization and remediation methods. We have refined our DNAPL strategy during this period based on the results of the various tests and through advances in technology documented in the literature and in regulatory guidance. The current SRS DNAPL strategy is documented in the form of a flow chart (Figure 7.1) that defines our approach to DNAPL management. Importantly, the DNAPL strategy is integrated into the RCRA groundwater corrective action and is being developed within the context of an overall plan for clean up of this area. This allows us to select characterization and clean-up methods that are appropriate to the character and distribution of contaminants in the various portions of the overall A/M-Area contaminant plume. Technologies targeting DNAPL are applied to source areas. Less aggressive methods are proposed for primary dissolved plume (e.g., pump and treat, air sparging, and bioremediation), and sustainable-long term processes for the dilute-distal fringe (e.g., phytoremediation and other types of natural attenuation).

The DNAPL strategy that has evolved addresses source zone(s). The strategy emphasizes detailed depth-discrete delineation of subsurface DNAPL to optimize remediation. This is particularly critical for DNAPL treatment systems such as enhanced mobilization (e.g., using steam, cosolvents or surfactants) and in situ destruction methods (e.g., permanganate or Fenton's reagent) because the treatment costs are a strong function of target treatment volume (i.e., unit costs are \$/volume). A sequence of complementary low cost characterization methods ("toolbox") is used for the characterization activities. The resulting approach, similar to exploration geochemistry, maximizes information to refine the conceptual model of target DNAPL at a minimum cost. A second key feature of the strategy is that DNAPL treatment methods are categorized based on cost, logistics and aggressiveness. SRS developed criteria, principally based on DNAPL mass and the treatment zone volume, to assist in selecting the best technology for each discrete area of DNAPL accumulation. Large quantities of DNAPL are addressed with the most aggressive (i.e., expensive) methods; smaller quantities are addressed with less expensive methods. We also identified rapid response options for areas where DNAPL related modifications to existing operations/infrastructure are feasible. A final key feature of the strategy was development of criteria for identifying that a potential DNAPL area does not have sufficient contamination to justify a DNAPL specific remediation – this does not mean we are proposing no action for these sites. Such areas will still have high (but

not DNAPL) concentration levels. They are near the center of A/M-Area and will continue to be cleaned up by the groundwater and vadose zone systems until permitted levels are achieved.

The DNAPL strategy flowchart (Figure 7.1) can be divided into several inter-related modules:

- Characterization (Figure 7.2) This module covers the initial identification of potential (or suspect) DNAPL sources based on process data, monitoring data and "rules of thumb". The characterization modules also includes follow up activities for each suspect area to "confirm" the presence of DNAPL and to support remediation by delineating the quantity and location of residual DNAPL. Many of the technologies are selected as described in Cohen et al (1993). DNAPL behaviors (and ultimately the optimal remediation strategies) are different in the vadose zone versus the saturated zone. These differences are accounted for in the selection from the available technologies in the flow chart as each site is addressed. Within characterization, complementary approaches are used. For example, "screening" level headspace analysis provides vertically dense data in a cost effective manner. This information helps determine the most appropriate placement for monitor well screens or follow up DNAPL testing.
- Rapid Response (Figure 7.3) This module provides a mechanism to implement a DNAPL targeted clean-up action by reconfiguring or modifying existing infrastructure. The availability of a rapid response option will allow SRS and the South Carolina Department of Health and Environmental Control (SCDHEC) to maintain and improve the performance of the on-going corrective action. Rapid response is for cases where the response is already described in the RCRA permit and for activities that do not involve new or substantial permit issues (e.g., no new types of underground injections, etc.). Note that the selection and operation of a rapid response is typically done in parallel to continued characterization and possible implementation of a more robust treatment later. A good example of this is the operation of SVE at the 321-M Solvent Storage Tank followed later by Dynamic Underground Stripping (steam enhancement to SVE).
- Technology (Figure 7.4) This module outlines the process for identifying appropriate DNAPL remediation activities and developing plans and schedules. Importantly, we have identified two categories of remediation targeting "large" volume source areas and "low" volume DNAPL sources. This structure clearly captures the important concept that the type of technology that can be implemented for large sources (e.g., steam) is not practical for small areas of DNAPL accumulation. A group of technologies appropriate to such sites has been identified based on our data.
- Regulatory (Figure 7.5) This module identifies the proposed steps in implementing DNAPL targeted clean up activities.

The flowchart consists of boxes and diamonds. Each of the boxes describes an activity or action, and each of the diamonds represents a decision. Within each activity, several technologies/approaches are used to obtain the information for the next decision. More detail on the approaches and technologies in each box are provided in Table 7.1 and the logic/basis of the various decisions represented by each diamond are discussed in Table 7.2. Characterization technologies, for example, are listed with brief descriptions of their capabilities and applicability and references that document their performance in implementation as we propose. This generic flowchart, implemented for each potential DNAPL area, will improve our ability

to document our progress, scope, schedule and plans. We can set goals to be at specific decision points and discuss the status for each source area in a standard and structured fashion. The DNAPL strategy identifies where technology limitations currently exist and provides a framework that allows demonstration of new technologies. The structure of the flowchart provides a framework for and simplifies inclusion of new characterization and remediation methods as they prove valuable in the future.

### A/M Area DNAPL Program Flowchart

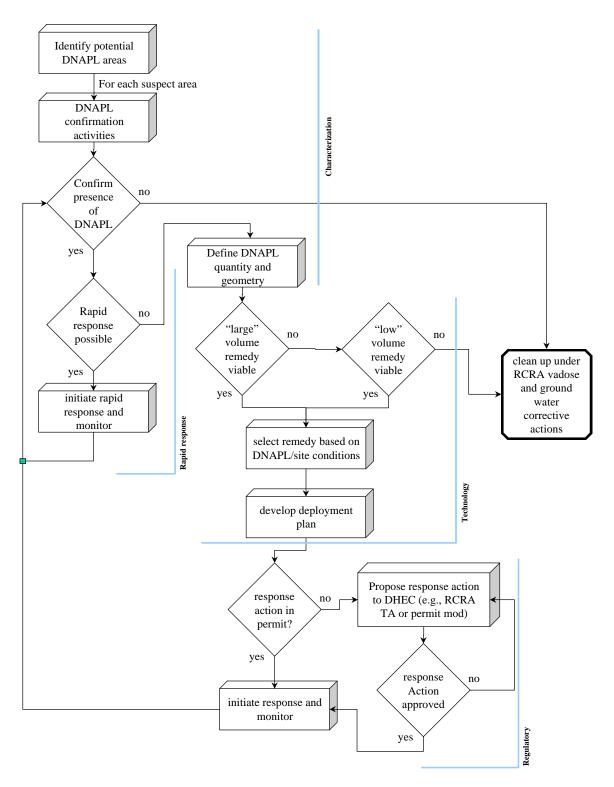


Figure 7.1. Overall A/M-Area DNAPL Strategy

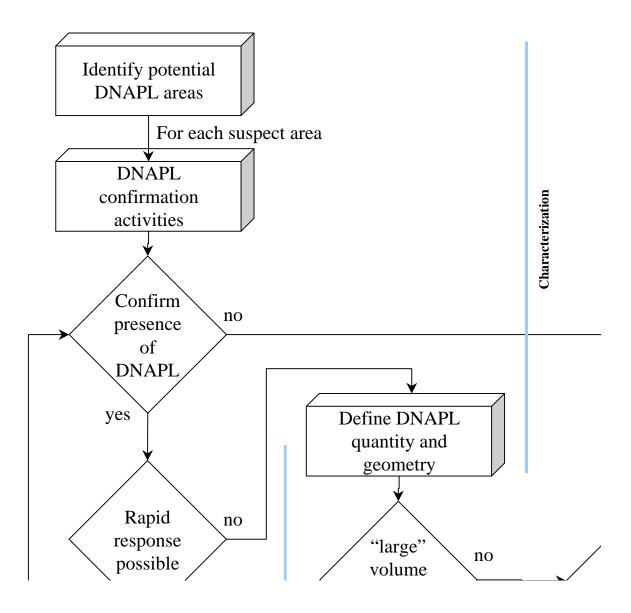


Figure 7.2. Characterization Module of the A/M-Area DNAPL Strategy

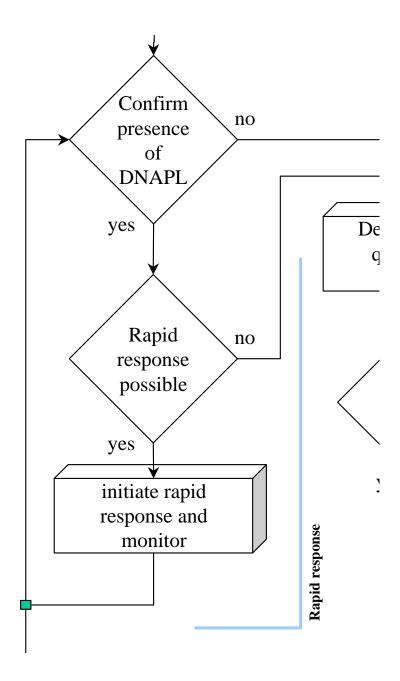


Figure 7.3. Rapid Response Module of the A/M-Area DNAPL Strategy

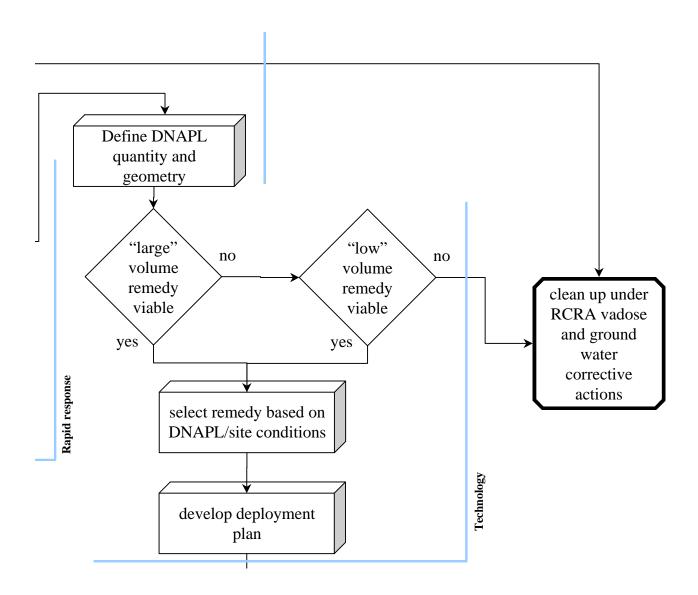


Figure 7.4. Technology Module of the A/M-Area DNAPL Strategy

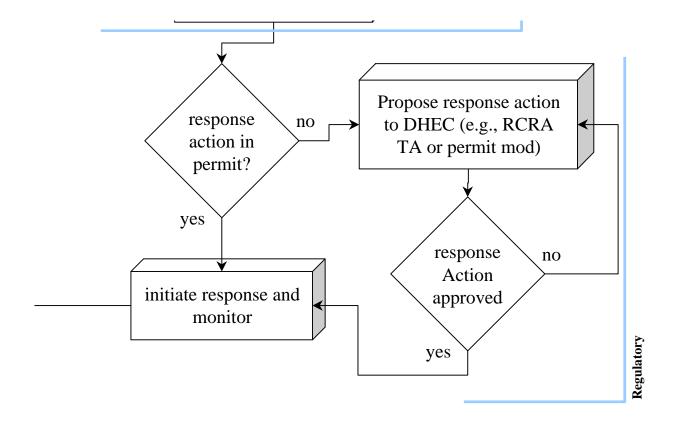


Figure 7.5. Regulatory Module of the A/M-Area DNAPL Strategy

# TABLE 7.1. Detail of the Activities and Techniques Used to Support the A/M-Area DNAPL Program

## Identify Possible / Suspect DNAPL Areas (Identification based on at least one of the following)

one of the following)					
Historical Information	- Recorded discharge of DNAPL solvents to the environment.				
and Process Records	- Recorded leakage of DNAPL solvents to the environment				
(see Looney et al., 1992;	- Documented DNAPL solvent storage area or DNAPL				
Jackson et al., 1996;	solvent usage facility				
Jarosch et al., 1997;	- Other potential DNAPL release areas that can be inferred				
Marine and Bledsoe,	from process records or interviews.				
1984, and others)					
DNAPL indicators in	- Groundwater concentrations > 1% or 10% of solubility from				
Groundwater	traditional monitoring wells (wells with 5' screen interval or				
Monitoring Database	longer). Two different screening levels are used to help				
(see Looney et al., 1992;	prioritize follow up confirmation activities.				
Jackson et al., 1996)	- Monitoring well concentrations that exhibit high variability				
	between sampling intervals or that change rapidly in				
	concentration				
Miscellaneous indicators	- Caliper logs in existing monitoring wells (deformation of				
(see Looney et al., 1992;	PVC casing may indicate the influence of DNAPL)				
Cohen et al, 1993, and	- Unexpected intervals of high readings in natural gamma				
others)	geophysical logs (due to partitioning of radon into NAPL				
	from both water and air phases)				
	- Unexpected intervals if low or high readings in electrical				
	geophysical logs (due to presence of either low conductivity				
	NAPL or high conductivity co-disposed aqueous wastes)				

#### DNAPL Confirmation Activities

Direct DNAPL Observation (see Cohen et al, 1993; Rossabi et al., 2000; Looney et al., 1992; and others)  - Identification of DNAPL in the sumps of groundwater monitoring wells using clear bottom filling bailer or similar method (useful for wells installed with intake screens and sumps near potential DNAPL controlling aquitards) - Drainage of separate NAPL phase from collected core In situ visualization of DNAPL using remote video system such as the GeoVis If DNAPL is collected, it's composition is analyzed for DNAPL constituents and co-contaminants (inorganics and trace organics such as polychlorinated biphenyls) to assist in technology decisions	DNAPL Commination A	Acuvities					
(see Cohen et al, 1993; Rossabi et al., 2000; Looney et al., 1992; and others)  method (useful for wells installed with intake screens and sumps near potential DNAPL controlling aquitards) - Drainage of separate NAPL phase from collected core In situ visualization of DNAPL using remote video system such as the GeoVis If DNAPL is collected, it's composition is analyzed for DNAPL constituents and co-contaminants (inorganics and trace organics such as polychlorinated biphenyls) to assist in	Direct DNAPL	- Identification of DNAPL in the sumps of groundwater					
Rossabi et al., 2000; Looney et al., 1992; and others)  sumps near potential DNAPL controlling aquitards)  - Drainage of separate NAPL phase from collected core.  - In situ visualization of DNAPL using remote video system such as the GeoVis.  - If DNAPL is collected, it's composition is analyzed for DNAPL constituents and co-contaminants (inorganics and trace organics such as polychlorinated biphenyls) to assist in	Observation	monitoring wells using clear bottom filling bailer or similar					
Looney et al., 1992; and others)  - Drainage of separate NAPL phase from collected core In situ visualization of DNAPL using remote video system such as the GeoVis If DNAPL is collected, it's composition is analyzed for DNAPL constituents and co-contaminants (inorganics and trace organics such as polychlorinated biphenyls) to assist in	(see Cohen et al, 1993;	method (useful for wells installed with intake screens and					
others)  - In situ visualization of DNAPL using remote video system such as the GeoVis.  - If DNAPL is collected, it's composition is analyzed for DNAPL constituents and co-contaminants (inorganics and trace organics such as polychlorinated biphenyls) to assist in	Rossabi et al., 2000;	sumps near potential DNAPL controlling aquitards)					
such as the GeoVis.  - If DNAPL is collected, it's composition is analyzed for DNAPL constituents and co-contaminants (inorganics and trace organics such as polychlorinated biphenyls) to assist in	Looney et al., 1992; and						
- If DNAPL is collected, it's composition is analyzed for DNAPL constituents and co-contaminants (inorganics and trace organics such as polychlorinated biphenyls) to assist in	others)	- In situ visualization of DNAPL using remote video system					
DNAPL constituents and co-contaminants (inorganics and trace organics such as polychlorinated biphenyls) to assist in		such as the GeoVis.					
trace organics such as polychlorinated biphenyls) to assist in		- If DNAPL is collected, it's composition is analyzed for					
		DNAPL constituents and co-contaminants (inorganics and					
technology decisions		trace organics such as polychlorinated biphenyls) to assist in					
		technology decisions					

TABLE 7.1. Detail of the Activities and Techniques Used to Support							
the A/M-Area DNAP	L Program (continued)						
Indirect DNAPL Detection	Ribbon NAPL sampler (hydrophobic fabric that wicks NAPL from the formation and indicates location with oil soluble dye						
(see Rossabi et al., 2000; Cohen et al, 1993; and	marking) DNAPL spectra on Raman spectrometer (normally deployed						
others)	using fiber optics in a cone penetrometer (CPT) tip) NAPL and/or codisposed hydrocarbon spectra on laser						
	induced fluorescence spectrometer (normally deployed using fiber optics in a CPT tip)						
D 1 1 1 1 1	Solubilization of oil soluble dye in collected liquid sample						
Depth discrete sampling (see Cohen et al, 1993;	- Collect and analyze depth discrete (point) water samples using CPT or during standard drilling. In A/M-Area, samples						
Looney et al., 1992; Rossabi et al., 2000, and	are collected using several commercially available samplers (e.g., hydropunch, conesipper, BAT sampler, and others) and						
others)	analyzed by standard methods.						
	- Collect and analyze depth discrete (point) soil samples using CPT or during standard drilling. In A/M-Area, samples are						
	collected using available split spoon or wireline core devices,						
	immediately sealed and preserved in the field, and analyzed						
	<ul><li>by standard methods.</li><li>Collect and analyze depth discrete (point) soil gas samples</li></ul>						
	using CPT or during standard drilling. In A/M-Area, samples						
	are collected using a cone sipper or similar gas permeable						
	access device and by photoacoustic infrared spectrometry confirmed by gas chromatography.						
	- Obtain depth discrete water/soil gas concentrations using						
	investigational methods such as membrane interface probe						
	(concentration in gas or water is related to diffusion through						
	membrane and concentration inside probe system),						
	colorometric or optical concentration sensor (e.g., sensor based on fujiwara reaction where TCE causes color change in						
	pyridine based reagent), and others.						
Geophysical and	- Define lithological and geological (structural) controls on						
geotechnical	DNAPL movement to optimize sampling strategy using CPT						
confirmation activities	logs, ground penetrating radar (GPR), shallow seismic						
(see Looney et al., 1992, and others)	reflection profiles, etc. (routine activity)  Direct geophysical detection of DNAPI using amplitude and						
and outers)	- Direct geophysical detection of DNAPL using amplitude a frequency variations and offsets in GPR and shallow seismi						
	reflection profiling (investigational).						
In-situ Solubilization	- Inject and extract solution of cosolvent or surfactants and						
Tests (see Jackson and	look for significantly elevated concentration in extracted fluid						
Pickens., 1994; Jerome	from dissolution of DNAPL. This technique has had limited						
et al., 1996, and others)	success but may be useful in carefully selected scenarios.						

TABLE 7.1. Detail of the Activities and Techniques Used to Support
the A/M-Area DNAPL Program (continued)
Define DNADI Quantity and Commetry

Define DNAPL Quantity and Geometry								
Depth discrete sampling (see Cohen et al, 1993; Looney et al., 1992; Rossabi et al., 2000, and others)	Utilize depth discrete methods described above and supplement confirmation data to improve understanding of the type, quantity, distribution and extent of residual DNAPL in DNAPL contaminated area.							
Geological and Geostatistical Data Interpretation (see Marine and Bledsoe, 1984; Looney et al., 1992; Jackson et al., 1996; Parker et al., 1999, and others	Generate 2D (cross section and plan view) and 3D (e.g., Earthvision) descriptions of DNAPL source zone concentrations and mass.							
Partitioning Tracer Tests - PITT (see Mariner et al., 1999)	Test injects multiple tracers in a well and extracts in a second well. Estimates the presence and quantity of DNAPL between the wells by examining the difference in behavior of the various tracers. This is a relatively expensive, but potentially useful, technique that has not been used to date in A/M-Area. PITT may have most utility in pre-test and post-test characterization of an active DNAPL cleanup.							
Initiata Danid Dagnanga	and Manitan							
Optimize existing treatment systems to address residual DNAPL	Operate or modify existing remediation system, such as a vadose zone treatment SVE unit, to target or better address residual DNAPL. This action is contingent on appropriate regulatory concurrence, either through an existing permit or other authorization.							
Perform Limited Pilot Testing of Innovative Treatment System.	Install and operate limited pilot test on well-defined DNAPL target. These actions are contingent on appropriate regulatory concurrence, either through an existing permit or other authorization. These tests are intended to facilitate understanding of performance and design and to treat an isolated or well-defined portion of the DNAPL associated with one of the A/M-Area source zones. Examples of pilot tests to date include In Situ Oxidation Using Fenton's Reagent, Six-Phase Heating, and Radio Frequency Heating.							

# TABLE 7.1. Detail of the Activities and Techniques Used to Support the A/M-Area DNAPL Program (continued)

#### **Select Remedy Based on DNAPL / Site Conditions**

This step considers the quantity and nature of the DNAPL target (concentrated pool versus diffuse ganglia) and the target geometry (thin laterally extensive layer versus vertically extensive laterally defined source. An example of the latter case is the 321-M Solvent Storage Tank where steam flushing of the vadose zone and shallow groundwater was selected. Existing clean up methods to be considered are classified into three groups to facilitate consideration:

- Enhanced Removal (examples include Dual Media Extraction, Surfactant Flushing, Cosolvent Flushing, Six Phase Heating, and Steam Flushing).
- In Situ Destruction: In Situ Bioremediation (normally anaerobic for PCE containing DNAPL), In Situ Oxidation (Fenton's), and In Situ Oxidation (Permanganate).
- Source Zone Isolation Methods: Capping may be useful as a temporary action that provides some benefit prior to identification and implementation of DNAPL specific remediation. In general, however, this is not normally recommended as a sole response since isolation is difficult and has not been successfully performed even under well-controlled experimental conditions.

Classifying the technologies by their primary mode of action encourages consideration of a large number of options and provides a structure to rapidly compare and contrast the options in a rapidly developing and competitive commercial market. The various commercial exemplars are constantly being evaluated and improved.

#### **Develop Deployment Plan**

This step consists of defining and describing the planned action, including: design basis, proposed operational protocol, monitoring plan, contingencies, potential technical problems/issues and actions taken to monitor or mitigate them, and regulatory plan.

#### **Propose Response Action to DHEC**

Propose the response action to DHEC. If action is deemed appropriate, develop an appropriate strategy to permit and implement the activity. This might entail a RCRA permit modification, a Temporary Authorization, or another appropriate type of regulatory approval. For DNAPL clean-up methods, other types of regulatory approval (notably underground injection control permits are often needed to approve addition of the reagents necessary to enhance removal of or destroy DNAPL)

#### **Initiate Response and Monitor**

Perform clean-up action (operate and monitor) and report to the regulators as agreed in the regulatory approval process.

## TABLE 7.2. Detail of the Decisions and Logic within the A/M-Area DNAPL Flowchart

#### **Confirm Presence of DNAPL**

**Yes** = collection and/or observation of separate phase liquid, or concentrations in water sample >= solubility, or concentration in soil gas sample >= vapor pressure, or concentration in bulk soil sample >= calculated DNAPL level (based on porosity, expected water content, etc.), or staining on ribbon NAPL sampler, or solubilization of oil soluble dye in liquid sample, or Raman (or similar) spectrometer confirmation of DNAPL, or direct *in-situ* visualization of DNAPL (using video visualization system such as GeoVis), or DNAPL solubilization during cosolvent/surfactant injection-extraction testing, or observation of other NAPL specific diagnostic phenomena (e.g., differential tracer partitioning).

**No** = very low concentrations (e.g., less than 1 ppmv soil gas concentrations for TCE and PCE) in depth discrete samples or negative findings from at least two methods listed above. Methods to be selected to provide maximum DNAPL sensitivity under site specific conditions.

#### Rapid Response Possible

Yes = Existing permitted remedy is in place that can be modified to provide improved DNAPL targeted performance (e.g., SVE system), or innovative/pilot scale DNAPL treatment possible that is within scope of RCRA permit or that can be implemented in a straightforward manner using an expedited Temporary Authorization (TA).

No = No existing or rapidly implementable treatment available for identified DNAPL

#### Large Volume Remedy Viable

Yes = 1) Target DNAPL zone is sufficiently defined to allow safe-robust design and engineering of treatment (i.e., to avoid inadvertent spread of contamination or other adverse collateral environmental damage), and 2) target zone contains, or is believed to contain, sufficient DNAPL to justify aggressive treatment action. See Jerome (*et al.*, 1997) who documents that several hundred pounds of target DNAPL are needed to justify large volume remedies under A/M-Area conditions. Aggressive treatments use large amounts of energy and/or strong chemical reagents that should be used only if sufficient source material is present.

No = Poorly defined target zone and/or insufficient DNAPL mass (< 100's of pounds) to justify aggressive remediation technology.

#### **Low Volume Remedy Viable**

Yes = 1) Target DNAPL zone contains lower quantities than listed above, and 2) DNAPL is accessible and amenable to available less aggressive (lower energy, less corrosive chemistry, etc.) methods such as periodic pumping or bailing of accumulated separate phase material.

No = "Small" quantities of diffuse or inaccessible DNAPL that are not amenable to available recovery/removal options.

# TABLE 7.2. Detail of the Decisions and Logic within the A/M-Area DNAPL Flowchart (continued)

#### **Response Action in Permit**

Yes = Proposed Response Action is listed in RCRA Part B Permit or approved modification or existing RCRA Temporary Authorization. Note that additional permit approvals are often required for DNAPL treatment (notably underground injection control permits or air permits) that must be obtained prior to initiating activities.

No = self explanatory

#### Response Action Approved

Yes = Approval of proposed activity as a modification to the RCRA Permit, a Temporary Authorization, or by any other valid direction from SCDHEC.

No = self explanatory

#### 7.2 DNAPL Strategies for Individual Source Terms

The three largest DNAPL sources in the A/M-Area are the A-014 Outfall, the M-Area Settling Basin and the 321-M Solvent Storage Tank. A former confirmed source that is approaching clean-up levels is the process sewer leading to the M-Area Settling Basin. Additional potential sources are the process facilities, buildings 313-M, 320-M, 321-M and 305-A, their associated storage facilities, the M-Area process sewer leading to the A-014 outfall, releases in SRTC, maintenance areas and related A/M-Area facilities. All of these areas can be classified into one of three categories: Storage Areas, Use Areas and Disposal Areas. One of the three primary sources is included in Storage Areas. This is the 321-M Solvent Storage Tank, where solvent was received from railroad cars and stored until needed by the processing facilities within M-Area and other locations on SRS. Other storage areas include the rail storage east of building 313-M, the drum loading area south of 313-M, and building 713-A. The Use Areas consist of the majority of the potential sources. These are buildings 305-A, 313-M, 320-M and 321-M, maintenance areas, potential release sites in SRTC and the 700 Area. The Disposal Areas contain two of the three primary sources, the M-Area Settling Basin and the A-014 Outfall, as well as the M-Area process sewer, the M-Area Settling Basin process sewer and the swampy area where building 321-M now stands. In the sections below we summarize key information and work through the flowchart for each of these facilities.

#### 7.2.1 STORAGE AREAS

The storage areas consist of 321-M Solvent Storage Tank, rail storage east of building 313-M, drum loading south of 313-M, and building 713-A which was the Central Stores Facility.

#### 7.2.1.1 321-M Solvent Storage Tank

This is a known source of DNAPL. Identification activities involved researching SRS records to determine use, duration and records of spills. The solvent storage tank is located west of the 321-M facility and began operation in 1957. This facility consisted of a 17,000 gallon storage tank with associated piping and equipment necessary to off-load solvent from rail-cars to the storage tank and to distribute solvent to the other process facilities in the M-Area and across the SRS. This facility served as the primary point for the storage and distribution of solvent in the M-Area except for the period between 1962 and 1970, during which PCE was introduced into the 313-M process and would have required local storage. According to Marine and Bledsoe (1984), numerous undocumented spills and leaks occurred in the vicinity of the solvent storage tank from off-loading the railroad cars. At the 321-M Solvent Storage Tank one spill of significance is reported to have occurred in October 1975. A cracked ceramic seal on a transfer pump resulted in an estimated 1,200 gallons of PCE being released to the environment. The incident report states that there was no evidence of PCE puddling on the ground.

This information provided sufficient evidence to conduct DNAPL confirmation activities. The initial characterization data are available from chemical analysis of soil plugs collected and analyzed in 1984 during the installation of monitoring well clusters MSB-

23, -26, -27 and -28 (Marine and Bledsoe, 1984). Total solvent concentrations in soil samples collected at MSB-23 were elevated, with concentrations exceeding 6,000 ppb at an elevation of 300.4 ft msl (70 ft bgs) and reaching 28,000 ppb at an elevation of 260.4 ft msl (110 ft bgs) immediately above the water table. Additional characterization of this area was performed by CH2M Hill (CH2M Hill, 1990). A total of 28 shallow soil gas samples were taken around the tanks and railroad tracks. TCE was detected in approximately 67% of the samples, with concentrations ranging from 0.11 to 4,200 parts per billion in vapor (ppbv). PCE was detected in all of the samples, with concentrations ranging from 0.12 to 570,000 ppby. TCA was detected in all but one of the samples, with concentrations ranging from 0.90 to 3,000 ppbv. Four soil borings (SRM-101-B through SRM-104-B) were drilled in the immediate vicinity of the solvent storage area. Significant concentrations of TCE and PCE were detected in soil samples collected from numerous intervals within each of the four borings. The overall highest concentrations of solvents were detected in soil samples collected from 356.7 ft msl to 335.7 ft msl (14 to 35 ft bgs) at boring SRM-101-B. PCE was detected in this interval at concentrations as high as 3,000 parts per million (ppm). Significant concentrations ranged in elevation from 365 ft msl (5 ft bgs) to the top of the water table (approximately 235 ft msl [135 ft bgs]) at each boring. As a result of this data an active soil vapor extraction (SVE) system was installed and began operation in 1995. The SVE system represents a rapid response for DNAPL in the vadose zone and has removed 28,238 pounds of solvent during its operation.

Characterization investigations from 1992 through 1997 were conducted to evaluate the lateral extent of (primary emphasis) and change in vertical contaminant distribution (secondary emphasis) (Jarosch et al, 1998). The results of the soil gas and soil plug samples indicated very high soil concentrations (>1000 ppmw) at shallow depths (< 50 ft bgs) and consisting primarily of PCE. This shallow contamination is confined to the immediate vicinity of the tanks on the eastern and southern sides of the pad. The shallow concentrations showed very little change since the CH2M Hill report of 1990. Concentrations less than 10 ppmw were observed down to the water table where TCE predominates. Coring in 1999 indicated that DNAPL concentrations are still present in pockets within the shallow vadose zone. The zone selected for a source zone remediation was determined to be 100 feet by 100 feet by 160 feet deep. This area encompasses the area of the solvent storage tank and associated pad and transfer facilities located to the south east of the pad. The depth includes the vadose zone and the water table down to the Green Clay, considered the first confining zone in that immediate area. The action chosen for this location is steam flushing combined with hydrous pyrolysis, also known as Dynamic Underground Stripping. This DNAPL treatment will supplement the ongoing SVE and groundwater pump and treat system. The DUS treatment plan has been submitted to SCDHEC and approval has been granted. Deployment of this technology began in April 2000. The active steaming is scheduled to be complete in May 2001.

The activities described above represent a relatively complete implementation of the A/M-Area DNAPL Strategy as shown in Figure 7.6. The flowchart depicts the SVE implementation as a rapid response and the subsequent additional characterization and implementation of DUS.

# **Source Specific DNAPL Flowchart - 321M Solvent Storage Tank**

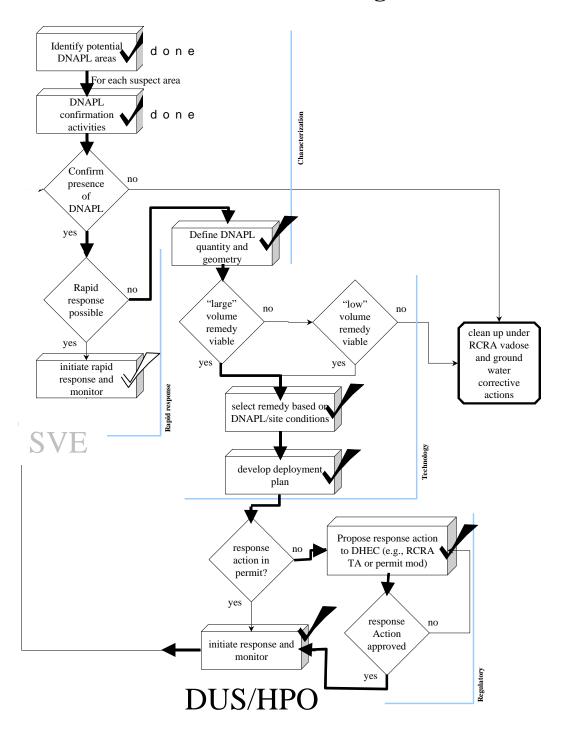


Figure 7.6. A/M-Area DNAPL Strategy applied to the 321-M Solvent Storage Tank Area

#### 7.2.1.2 Rail Storage East of Building 313-M

Historical information indicates the TCE was shipped to the 313-M facility in rail tank cars. These tank cars were used for a storage facility while located on the railroad siding, which is located east of the building. The TCE was pumped from the tank cars into the pipeline to 313-M. Spills are likely to have occurred during tank car unloading operations, but none are documented (Marine and Bledsoe, 1984). Due to the uncertainty of the presence or absence of DNAPL, the next step is to perform DNAPL confirmation activities at this location. This activity can be conducted in conjunction with the DNAPL confirmation sampling of Building 313-M. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area (and the similar storage areas discussed herein) is shown in Figure 7.7.

#### 7.2.1.3 Drum Loading South of Building 313-M

As M-Area was the primary user of chlorinated solvents at SRS, many of the shipments came to this area. To accommodate shipping of these solvents to other use areas at SRS, a drum loading facility was established at the south end of building of 313-M. As with the rail storage area described above, there is no documented evidence of spills (Marine and Bledsoe, 1984). Due to the uncertainty of the presence or absence of DNAPL, the next step is to perform DNAPL confirmation activities at this location. This activity can be conducted in conjunction with the DNAPL confirmation sampling of Building 313-M. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area (and the similar storage areas discussed herein) is shown in Figure 7.7.

#### 7.2.1.4 Central Storage Facility, 713-A

This facility dispensed small quantities of chlorinated solvents to buildings 773-A and 717-A from the mid-1960's through May 1978. The transition from TCE to PCE came in August 1977. The solvents were stored in 55-gallon drums from which it was pumped into smaller containers for distribution. This storage facility was in a small building at the north end of building 713-A, where paint was also stored (Marine and Bledsoe, 1984). There is no documented evidence of spills at this location. Due to the uncertainty of the presence or absence of DNAPL, the next step is to perform DNAPL confirmation activities at this location. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area (and the similar storage areas discussed herein) is shown in Figure 7.7.

### Source Specific DNAPL Flowchart -Rail Storage East of Building 313-M, Drum Loading South of Building 313-M, 713-A

**Central Storage Facility** 

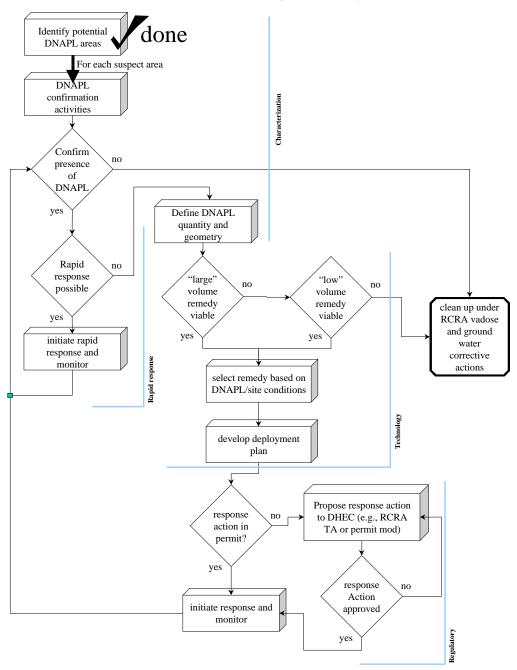


Figure 7.7. A/M-Area DNAPL Strategy applied to the several smaller storage areas

#### 7.2.2 USE AREAS

The Use Areas comprise the largest number of the potential DNAPL sources, but they represent a relatively small release quantity (compared to the large disposal areas – the M-Area Settling Basin and the A-014 Outfall). The Use Areas are buildings 305-A, 313-M, 320-M and 321-M, 773-A, 717-A, 703-A and 777-10A. These buildings are located within SRTC, M- Area, Upper 700 and Lower 700 Areas.

## 7.2.2.1 313-M (Slug Manufacturing Facility), 320-M (Target Manufacturing Facility) and 321-M (Fuel Manufacturing Facility)

Degreasing facilities were located in each of these three buildings. An estimated quantity of 13 millions pounds of chlorinated degreasing solvents were used in these three buildings between 1952 and 1982. The degreasing solvent use changed from TCE to PCE to 1,1,1-TCA through this period, with the changeover occurring at different times in different facilities. The spent solvents were either drained into the process sewers, or pumped into drums and then distilled for reuse. In the 1970s, still bottoms, degreaser sludges, and some solvent were collected in drums and stored on concrete pads awaiting distillation recovery. Based on review of the design drawings for these buildings, the primary locations of interest are the degreasing rooms and the sumps where solvent may have accumulated. DNAPL confirmation activities are planned for the end of FY00 and through FY02 for these three facilities.

#### 7.2.2.2 Building 305-M

During 2000, review of historical documentation (Plumlee, *et al.*, 1953) led to the identification of building 305-M as a potential source of DNAPL. The next step will be to initiate DNAPL confirmation activities. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area (and the similar use areas discussed herein) is shown in Figure 7.8.

#### 7.2.2.3 Building 773-A (SRTC)

Building 773-A has been identified as a potential release site for DNAPL. Historical documentation (Marine and Bledsoe, 1984) indicates building 773-A is a potential source of DNAPL. As with building 305-A, the next step is to initiate DNAPL confirmation activities. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area (and the similar use areas discussed herein) is shown in Figure 7.8.

#### 7.2.2.4 Lower 700 Area

Historical information led to the identification of building 777-10A as a potential release site for DNAPL. Conversations with former employees who worked in this building indicate that chlorinated solvents were used to wipe down the walls of some rooms. The next step is to initiate DNAPL confirmation activities. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area (and the similar use areas discussed herein) is shown in Figure 7.8.

#### 7.2.2.5 *Upper 700 Area*

During 1999, review of historical documentation led to the identification of the former print shop facilities in building 703-A as a potential release site for DNAPL. Shallow soil gas sampling was completed using the CPT truck in 1999. The results did not indicate the presence of DNAPL. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area is shown in Figure 7.9.

### Source Specific DNAPL Flowchart -Buildings 313-M, 320-M, 321-M, 305-A, 773-A and the Lower 700 Area

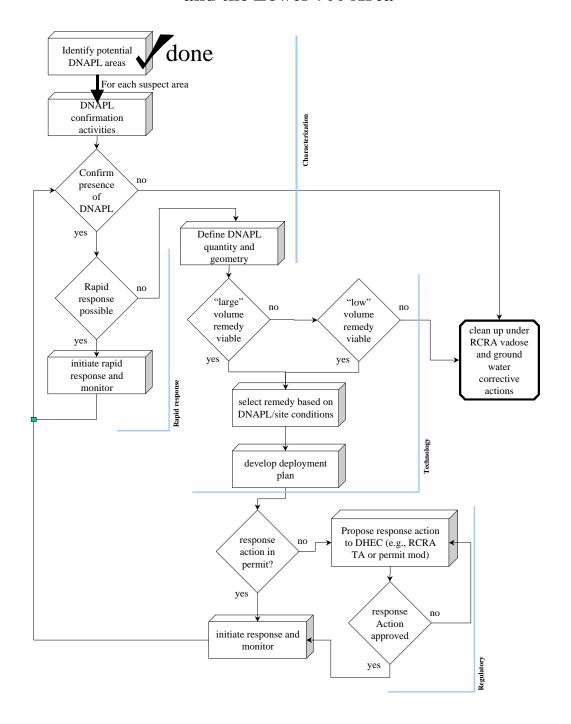


Figure 7.8. A/M-Area DNAPL Strategy applied to the DNAPL use areas (excluding Upper 700 Area)

## Source Specific DNAPL Flowchart -Upper 700 Area

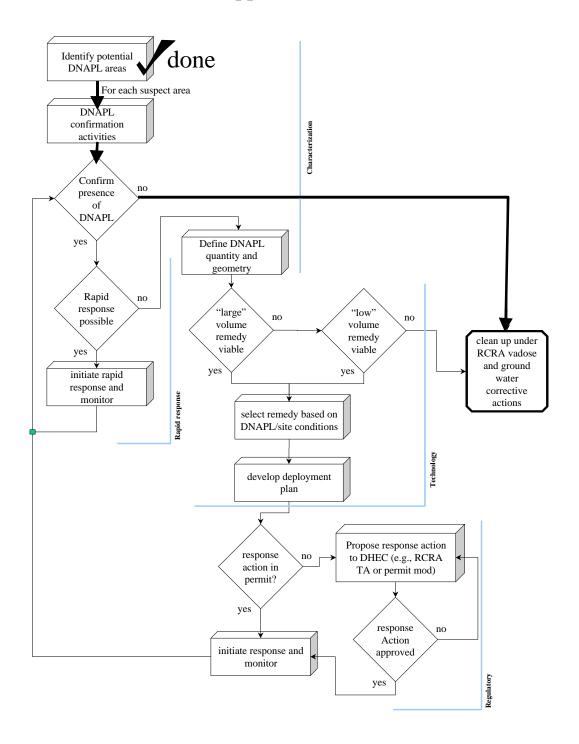


Figure 7.9. A/M-Area DNAPL Strategy applied to the Upper 700 DNAPL use area

#### 7.2.3 SOLVENT DISPOSAL AREAS

The Solvent Disposal Areas were the primary sources of DNAPL to the environment in A/M-Area. These areas consist of the M-Area Settling Basin, M-Area Settling Basin process sewer, A-014 outfall, M-Area process sewer (leads to A-014 outfall), and the swampy area on which building 321-M now sits. Waste effluents from the Use Areas were discharged to the Disposal Areas process sewers beginning in 1952. The M-Area settling basin was built and began receiving waste in 1958.

#### 7.2.3.1 M-Area Settling Basin Process Sewer

M-Area process wastewaters were discharged from buildings 313-M, 320-M and 321-M to the M-Area Settling Basin from 1958 to 1985 via a 30-inch diameter terra cotta underground sewer line. It is estimated that 2 million pounds of chlorinated solvents may have been released to the M-Area Settling Basin through this sewer line. A television survey made in 1982 of the process sewer line to the M-Area Settling Basin showed cracks in the terra cotta pipe. In places fine plant roots penetrated into the sewer (Marine and Bledsoe, 1984). This pipe was relined with a 12-inch PVC liner in December 1983 (Pickett, 1985). Characterization of the process sewer line was conducted from November 1984 through March 1985 consisting of soil gas and soil samples. The locations with the highest soil gas numbers were the basis for selecting the sites for collecting the soil samples. Soil samples were collected to a depth of 8 feet below the bottom of the process sewer line (approximately 356 ft msl). Three locations were selected with one location at the manhole closest to the basin. Four soil cores were collected at each location, with two additional cores collected at one location. These two additional cores were slanted underneath each side of the sewer line to enable collection of samples directly under the line. The results indicated levels as high as 765 ug/g (ppmw) PCE directly below the sewer line at a depth of 3 feet (approximately 361 ft msl). The data indicated no significant lateral spread of the contamination (Pickett, 1985). The early data and later characterization work (cone penetrometer work conducted in 1992 and the like) suggested that a significant fraction the original released DNAPL solvents remained trapped in the vadose zone along the sewer line (Looney, 1992).

Based on the available data, we performed a variety of DNAPL related actions. Several pilot and research studies, as well as full scale soil vapor extraction were implemented in the high concentration areas – all serving as rapid responses that address residual source DNAPL in these areas.

A soil vapor extraction pilot test conducted along a portion of the sewer line by Terra Vac and SRS in 1987 confirmed the vadose zone in the vicinity of the sewer was contaminated with large quantities of residual solvent, verified the viability of SVE, and provided design data for subsequent full scale implementation. The SVE pilot system was operated for 21 days to provide sufficient data to meet these objectives. Over 1500 pounds of chlorinated solvent were removed during the test. In 1989 as part of the M-Area Settling Basin closure, this process sewer was excavated. In 1988, a pair of horizontal wells was installed – one above the water table and one below the water table. These wells were

used as an SVE and sparge well, respectively, provided a system for combined remediation of the vadose zone and shallow groundwater. Further, these particular wells represented an early, and key, step in the use of horizontal drilling in environmental applications. The pilot study of the system, known as the In Situ Air Stripping Demonstration, was operated between July 27 and December 13, 1990. This test removed approximately 16,000 pounds of chlorinated solvent during the 3 month test (CH2M Hill, 1990).

Based on the data collected during the In Situ Air Stripping Demonstration (measured increases in microorganisms including TCE degraders) an In Situ Bioremediation pilot test was initiated. This test used natural gas (methane) and other nontoxic nutrients to stimulate organisms that have the capability to degrade moderate concentrations of residual solvent. An additional 17,000 pounds of solvent were removed from (or destroyed in) the subsurface during this 14 month test (Hazen et al., 1994).

We performed two additional pilot tests along this sewer line. The objective of these tests, both heating technologies, was to speed up the removal of residual solvent trapped in vadose zone clays. The two heating technologies employed were radio frequency (RF) heating and direct resistive (joule) heating. In the former, low frequency radio waves interact with the atoms of water and sediment to generate heat (Jarosch et al, 1994), while in the latter, the block of earth acts as the resistor (heating element) in the process (Gauglitz, et al).

In 1995, a full-scale RCRA vadose zone SVE treatment was initiated in the area of the process sewer line. This effort, utilizing the original horizontal wells, three new horizontal wells, and vertical extraction wells, providing contaminated vapors to two SVE units has provided significant additional removal of residual DNAPL solvent. The full scale operation has removed an additional 57,000 pounds of chlorinated solvents.

The total contaminant mass removal from the various pilot scale, research and full scale rapid response actions along the M Basin Process Sewer line is approximately 91,500 pounds (sum of above numbers). A site specific version of the A/M-Area DNAPL Strategy for this particular suspect DNAPL Area is shown in Figure 7.10. Work continues to characterize the nature and extent of residual source along the process sewer. Post-test characterization reports and vadose zone characterization data suggest that the rapid response actions have been successful in addressing residual source DNAPL. Nonetheless, as discussed in Section 8.0, additional characterization work on this source continues to support orderly close-out of this particular former DNAPL source.

## **Source Specific DNAPL Flowchart -**

#### **M Basin Sewer Line**

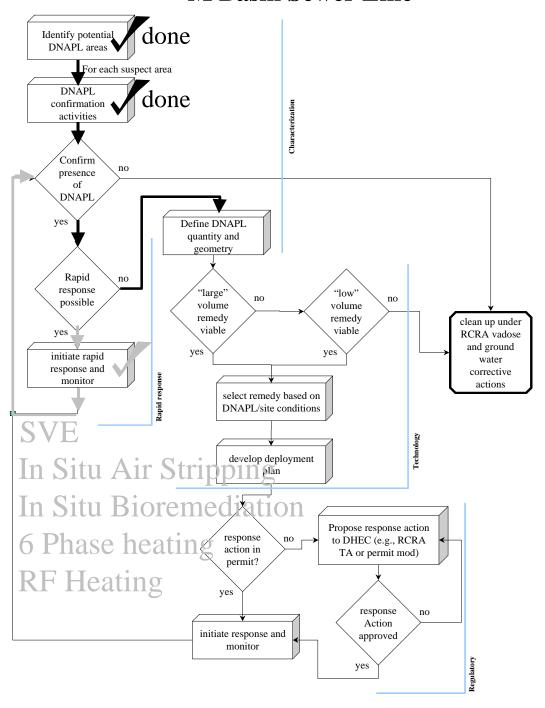


Figure 7.10. A/M-Area DNAPL Strategy applied to process sewer leading to the M-Area Basin

#### 7.2.3.2 *M-Area Settling Basin*

M-Area process wastewaters were discharged from buildings 313-M, 320-M and 321-M to the M-Area Settling Basin from 1958 to 1985 via a 30-inch diameter terra cotta underground sewer line (discussed above). The receiving facility, the M-Area Settling Basin, was an eight million gallon capacity, unlined surface impoundment designed to settle and contain uranium and other dissolved metals discharged from fuels and target fabrication processes. The M-Area waste stream contained metals (nickel, aluminum, uranium, lead), acids, caustics, and solvents from the aluminum-forming and electroplating processes. Under the RCRA Hazardous Waste Listings promulgated in 1980, the waste stream was classified as F006-electroplating waste (Looney, 1992). It is estimated that 2 million pounds of chlorinated solvents may have been released to the M-Area Settling Basin through this sewer line (Marine and Bledsoe, 1984).

Initial characterization activities involved construction of exploratory wells. RCRA type wells were installed from November 1979 through February 1981 around several of the facilities associated with the M-Area groundwater plume as part of the interim status requirements under the RCRA Part A Permit. Clusters MSB-1 through MSB-4 were installed around the M-Area Settling Basin. On June 28, 1981 analytical results from initial well sampling confirmed the presence of degreaser solvents around the M-Area Settling Basin. Soil and fluid sample analyses showed organic concentrations as high as 500 mg/L. In March 1982, 5 core holes were drilled inside the perimeter of the M-Area Settling Basin. The core holes were drilled to a depth of 15 ft beneath the bottom of the basin from a floating barge. The core holes were drilled at the 4 corners of the basin and at the center. The concentration in the eastern part of the basin opposite the inflow was much higher than in the remainder of the basin. The concentrations indicate the presence of pure solvent at the inflow and in the eastern part of the basin opposite the inflow. PCE levels as high as 2,000 µg/g (ppmw) were found in the upper 3 feet of soil and ranged from 10 µg/g to 500 µg/g to depths of 15 feet (Gordon, 1982). In 1985, 4 additional soil borings were drilled inside the perimeter of the M-Area Settling Basin with 4 borings drilled adjacent to the basin in the basin berm. The borings inside the basin were drilled to a depth of 6 feet and those outside the perimeter were drilled to a depth of 21 feet. The highest PCE concentration measured was 24.1 µg/g in the 0 to 1.0 foot sample located in the eastern part of the basin opposite the inflow. The average PCE concentration in the upper 2 feet was 1 µg/g. Neither PCE, TCE, nor 1,1-TCA was detected above detection limits in any soil sample from 2 to 6 feet deep inside the basin perimeter. The analysis showed no evidence of chlorinated solvents in the berm material. Analysis for inorganic contaminants was also conducted on the liquid and sludge in the basin and shallow underlying soil. Results indicated the metal contaminants (Al, Ni, U, Pb, Na) had been held in the sludge and shallow basin sediments (Pickett, 1985).

Based on the results of the characterization activities a closure plan was prepared, submitted to SCDHEC in 1984 and approved by SCDHEC in 1987 to close the M-Area Settling Basin by placement of a RCRA cap (Looney, 1992). As part of the closure the basin was dewatered and the liquid treated and sent to a permitted outfall. This was followed by stabilization of the sludge, which contained the majority of the inorganic contaminants. The stabilized sludge and cement mixture was placed back in the basin and

the low-permeability cap was then placed atop this material (Colven et al., 1985). In 1985 SRS submitted a RCRA Part B Permit Application to include M-Area HWMF post-closure maintenance, groundwater monitoring, and corrective-action systems. SCDHEC approved and issued the Part B permit in September 1987 with a periodic renewal required (Looney, 1992). Basin closure activities began in 1988 with completion in 1990.

In early 1990, 40 soil gas samples were collected along the fence perimeter of the closed M -Area Settling Basin. TCE was detected in one-fourth of the samples, with concentrations ranging from 0.02 to 3.8 ppbv. PCE was detected in all of the samples, with concentrations ranging from 0.03 to 2,700 ppbv. TCA was detected in every sample, with concentrations ranging from 0.07 to 75 ppbv. Based on the soil gas results, four locations were proposed for soil sampling using hollow-stem auger drilling. Of the four locations proposed, three locations were drilled with two of these completed as monitoring wells. These borings were located adjacent to the basin inlet, at the corner adjacent to the overflow ditch, and at the western corner of the basin. Two sample points measured TCE above 50 ppb. These were at the location adjacent to the basin inlet at sampling intervals of 45 to 50 feet below ground surface (bgs) and 95 to 110 feet bgs. The concentrations were 75 ppb at 45 ft, 68 ppb at 50 feet, 103 ppb at 95 ft, 112 ppb at 105 ft and 81 ppb at 110 ft (CH2M Hill, 1990).

Monitoring well MSB-3D, located adjacent to the northwest side of the closed basin, was installed in September 1990. This well is screened from 230.7 ft msl to 211.2 ft msl (128 to 147.5 ft bgs). During the first sampling in January 1991 a strong solvent odor was detected and a small amount of separate phase residue was observed in the bottom of a filtering apparatus. This well was resampled in February1991 to obtain a separate phase liquid sample. The analytical results from that sampling indicated TCE and PCE concentrations of 160 and 560 mg/L, respectively for the groundwater sample. Analysis of the separate phase indicated the presence of an organic liquid comprised almost exclusively of high concentration of PCE and TCE. In May 1991, 12 additional wells, within the vicinity of the M-Area Settling Basin, were sampled as had been done with well MSB-3D to obtain separate phase material, if present. No separate phase material was observed in any of these 12 wells. In September 1991 well MSB 3D was sampled again and 1.8 L of DNAPL were recovered. In December 1991 and February 1992 15 wells, identified as potential or known DNAPL wells, were sampled. A visible-dense phase was collected only in wells MSB-22 and MSB-3D (Looney, 1992).

In 1992 cone penetrometer studies were conducted that strengthened early work suggesting that a structural feature on the surface of the "green clay" -- in the form of a trough -- may serve as a pathway for DNAPL transport to the west and the north of the M-Area Settling Basin passing through the area near well MSB-76 (Looney, 1992). Additional characterization and data analysis, primarily aimed at "defining DNAPL quantity and geometry", were performed during the following years and summarized in Jackson et al., 1996. These efforts identified the presence of isolated DNAPL targets below the water table to the north and west of the basin. One of these was selected for a pilot study of in situ oxidation using Fenton's Reagent (Jerome et al., 1997).

In January 1997, pre-demonstration characterization activities were initiated for the purpose of final site selection then pretest characterization for a small-scale demonstration of an in situ oxidation technology for destruction of DNAPL. Two borings were drilled, one north of the inlet to the basin and one along a suspected DNAPL flow pathway west of the basin. The highest concentration in the boring north of the basin inlet was 4.48 ug/g PCE at an elevation of 258.6 ft msl (90 ft bgs). The boring along the suspected DNAPL flow pathway west of the basin indicated higher levels of PCE and TCE than the boring north of the basin inlet. Additional characterization along this suspected flow pathway identified concentrations indicative of pure solvent (PCE) at elevations ranging from 216 ft msl to 211 ft msl (138 to 143 ft bgs). Upon completion of the technology demonstration, post-demonstration characterization showed a marked decrease in PCE and TCE concentrations in the treatment zone. The oxidation of DNAPL by Fenton's Reagent was estimated to have destroyed 600 lbs of solvent. Continued monitoring of the wells installed for the demonstration showed a rebound of TCE and PCE in the aqueous phase. Subsequent soil plug sampling has confirmed that separate phase DNAPL solvents are not present and have not re-entered the test site. This suggests a continuing upgradient DNAPL contaminant source reintroducing contaminated water across the test zone (Jerome, 1997). The upgradient source is the vadose zone and shallow groundwater immediately beneath and downgradient of the former M-Area Settling Basin. These were highlighted as the focus of recent characterization efforts to support implementation of an appropriate DNAPL treatment technology.

Other miscellaneous studies that were performed during this time period included an alcohol injection extraction characterization test in existing wells to determine the presence or absence of DNAPL in the immediate vicinity of the well (Jerome et al., 1996) and a small scale study of a hydrophobic lance (Tuck et al., 1998). The lance concept used teflon (a hydrophobic surface) to slowly collect solvent from zones that have a continuous phase, but low quantities, of residual DNAPL. These two tests were equivocal and both technologies require additional development for any potential application.

From 1997 through 2000 characterization activities have continued around the M-Area Settling Basin to delineate the vertical and horizontal extent of contamination from this source. Soil borings were drilled adjacent to the basin and beneath the basin. Most borings were drilled to the top of the Green Clay to elevations of approximately 195 ft msl (160 ft bgs) with one boring drilled to the top of the Crouch Branch Confining Unit at an elevation of 128 ft msl (227 ft bgs). All borings beneath the basin were drilled to the top of the Green Clay. The borings beneath the basin were drilled at an angle to allow access below the basin without the need to compromise the existing RCRA cap. The data suggest contaminants are migrating from the basin toward the west and also to the southwest along structural "depressions" on the surfaces of low permeability intervals. The concentrations in the soil plug samples indicate the highest DNAPL source concentrations are present immediately below and adjacent to the source and do not indicate that a large volume of DNAPL is present at locations further from the source. The highest concentrations were detected in the angle boring drilled beneath the inlet for the basin within the lower vadose zone. In the water table below the basin, TCE and PCE concentrations indicate the presence of contamination, but do not suggest DNAPL

presence. The highest concentrations in this boring were 22.1  $\mu$ g/g of TCE and 198.3  $\mu$ g/g of PCE, at elevations of 262 ft msl and 240 ft msl, respectively. The angle boring on the southeastern and vertical boring on the western side of the basin did not have concentrations suggesting DNAPL. However, TCE and PCE are present in both locations (Jerome, 1998; Jerome, 1999). The data collected in FY2000 further substantiate the data gathered the past 3 years. The data from the vicinity of the M-Area Settling Basin have demonstrated the complexity of determining the quantity and location of DNAPL, especially distant or deep pockets below the water table. Future plans include continuing this activity and implementing source treatment as viable target accumulation zones are identified.

In 1995, a full-scale RCRA vadose zone SVE treatment was initiated in the area of the basin, utilizing two horizontal wells that are installed in the deep vadose zone beneath the capped area. This effort has provided significant removal of residual DNAPL solvent. The full scale SVE operation at the M-Area Settling Basin has removed 115,700 pounds of chlorinated solvents.

The total contaminant mass removal from the various pilot scale, research and full scale rapid response actions along the M- Area Settling Basin is approximately 116,300 pounds (sum of above numbers). A site-specific version of the A/M-Area DNAPL Strategy for this particular suspect DNAPL Area is shown in Figure 7.11. Work continues to characterize the nature and extent of residual source near the basin. As discussed in Section 8.0, additional DNAPL related work on this source area will continue.

# **Source Specific DNAPL Flowchart -**

## **M** Area Settling Basin

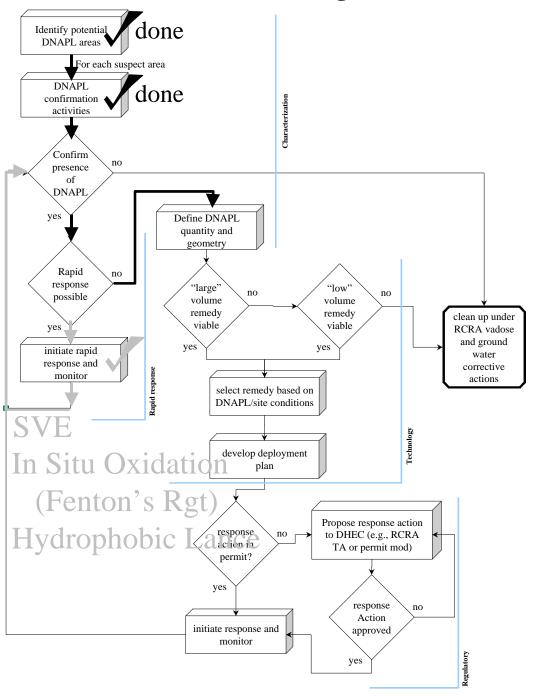


Figure 7.11. A/M-Area DNAPL Strategy applied to the M-Area Settling Basin

#### 7.2.3.3 *M-Area Process Sewer (leads to A-014 outfall)*

M-Area process wastewaters were discharged from buildings 313-M and 320-M to the A-014 outfall from 1952 through 1980 via a 30-inch diameter terra cotta underground sewer line. It is estimated that 1.5 million pounds of chlorinated solvents may have been released to the A-014 Outfall through this sewer line. A television survey made in 1982 of the process sewer line to the A-014 Outfall showed small cracks along most of the length of the terra cotta pipe. Also, the pipe near the discharge to the outfall was heavily corroded. This sewer line was relined in 1983 (Marine and Bledsoe, 1984). The process sewer line had numerous manholes located approximately 350 ft apart along the entire length of the system. In 1997 and 1998 two borings were drilled along the A-014 outfall using rotosonic drilling. The resulting data showed contaminated intervals, primarily TCE, below the water table. This suggests lateral dissolved plume migration at depth rather than vertical migration from an overlying source (Jerome, 1998). No significant levels of DNAPL solvent were identified in the vadose zone along this sewer line – closely spaced vertical samples were collected from the several representative manholes and from M-Areas underlying straight runs of the sewer line. Limited additional sampling of this potential source area is not currently planned unless new information is generated that suggests a particular location to study. As shown in Figure 7.12, this source is currently being remediated by the baseline RCRA groundwater corrective action and no additional DNAPL targeted work is scheduled.

# **Source Specific DNAPL Flowchart - Process Sewer leading to A-014 Outfall**

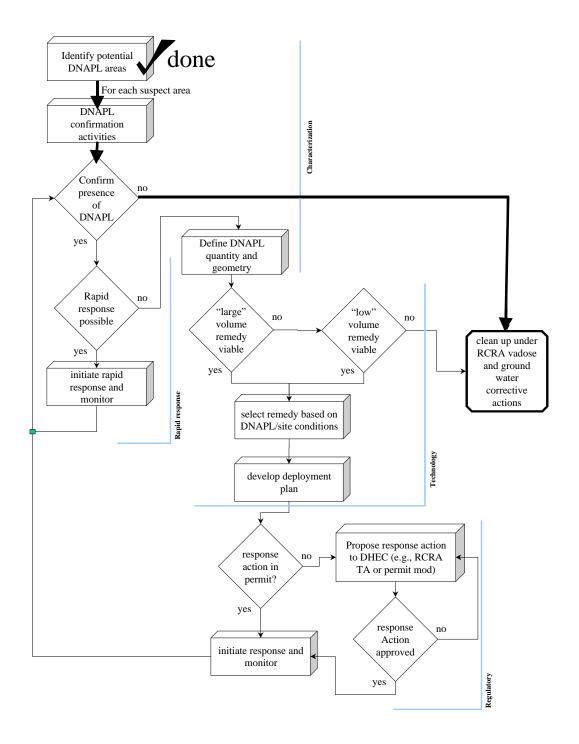


Figure 7.12. A/M-Area DNAPL Strategy applied to the process sewer leading to the A-014 Outfall

#### 7.2.3.4 *A-014 Outfall*

M-Area process wastewaters were discharged from buildings 313-M and 320-M to the A-014 outfall from 1952 through 1980. It is estimated that 1.5 million pounds of chlorinated solvents may have been released to the A-014 Outfall through the sewer line (Marine and Bledsoe, 1984). Of this quantity, 72 % was PCE, 27% was TCE, along with a small quantity of 1,1,1-TCA. The release rates and distributions were not constant over the active disposal period from the buildings. It is believed this may effect the distribution of the TCE and PCE in the subsurface (Jackson, 1999). Groundwater monitoring well data indicate a source of chlorinated solvents in the area of the present water discharge (CH2M Hill, 1990). In 1997 and 1998 three borings (MRS 11, 14 and 18) were drilled at the A-014 outfall using rotosonic drilling. The resulting data suggested the soil vapor extraction units are effectively remediating the vadose zone and the contaminants are being transported along the middle clay of the water table aquifer and then penetrating deep into water bearing zones. The relatively thin intervals (approximately 10 ft thick) of elevated PCE concentrations below the water table indicate that DNAPL accumulation areas in the vicinity are probable (Jerome, 1998). In 2000, two angle borings (MRS 32 and 33) and one vertical boring (MRS 34) were drilled along the outfall. The angle borings were drilled in an effort to detect vertical movement into the subsurface along a greater front than is possible with one vertical boring. MRS 32 detected concentrations of PCE indicative of DNAPL in the zone of 251 ft msl to 247 ft msl (107 to 110 ft bgs). A vertical boring was drilled, sampled for verification purposes and a vadose zone well installed in the contaminated zone.

In mid-1990 24 soil gas samples plus 5 duplicates were taken at the headwall of the A-014 outfall and along the stream. TCE was detected in 23 samples, will concentrations ranging from 0.38 to 25,000 ppbv. PCE was detected in every sample, with concentrations ranging from 1.4 to 230,000 ppbv. This work was followed up by drilling 3 soil borings that were sampled at 5-foot intervals. TCE and PCE were detected in most of the soil samples. Detectable concentrations above 50 ppb occurred consistently from approximately 266 ft msl to 261 ft msl (80- to 85- foot bgs) interval down to an elevation of 221 ft msl (125 ft bgs). One vapor extraction well and two vapor monitoring clusters were installed at the outfall area (CH2M Hill, 1990).

In 1995, a full-scale RCRA vadose zone SVE treatment was initiated in the area of the outfall. This effort has provided significant removal of residual DNAPL solvent. The full scale SVE operation at the A-014 Outfall has removed 166,100 pounds of chlorinated solvents.

In February and April 1999 cone penetrometer based characterization activities were conducted to evaluate shallow vadose zone contamination at the headwater of the A-014 outfall. Twenty-two locations were selected for the characterization. Techniques used were soil gas sampling, cone penetrometer probes for determining lithology and in-situ DNAPL detection Ribbon NAPL Sampler. The results indicate that DNAPL is present in the shallow (337-322 ft msl [10-25 ft bgs]) vadose zone near the headwater of the outfall.

The data indicate that although the DNAPL is within the radius of influence of ongoing remediation systems, the interval is not adequately being addressed due to the clayey-interbedded nature of the sediments of the shallow vadose zone at this particular site. To address this limitation and specifically target the identified DNAPL, a series of vertical extraction wells were installed in these zones for connection and configuration into the existing, permitted soil vapor extraction system located at the outfall. Based on the results of the characterization, it is postulated the infiltration associated with the headwaters of the outfall may impact the distribution and subsequent removal of DNAPL in the shallow vadose zone. Additional information is needed on the possible effects of this infiltration and on the effects of co-disposed liquids released to the outfall in the transport and distribution of DNAPL in the subsurface (Jackson, 1999).

The total contaminant mass removal from full scale rapid response actions along the A-014 Outfall is approximately 166,100 pounds (sum of above numbers). A site-specific version of the A/M-Area DNAPL Strategy for this particular suspect DNAPL Area is shown in Figure 7.13. Work continues to characterize the nature and extent of residual source near the outfall. A-014 Outfall is one of the earliest DNAPL sources in A/M-Area (receiving solvents prior to the construction of the M-Area Settling Basin). Because of this, planned work to "define the DNAPL quantity and geometry" will include both the shallow source (vadose zone), as well as an expanded program to identify deeper discrete DNAPL accumulation zones below the water table. As discussed in Section 8.0, additional DNAPL related work on this source area will continue.

## **Source Specific DNAPL Flowchart -**

### A-014 Outfall

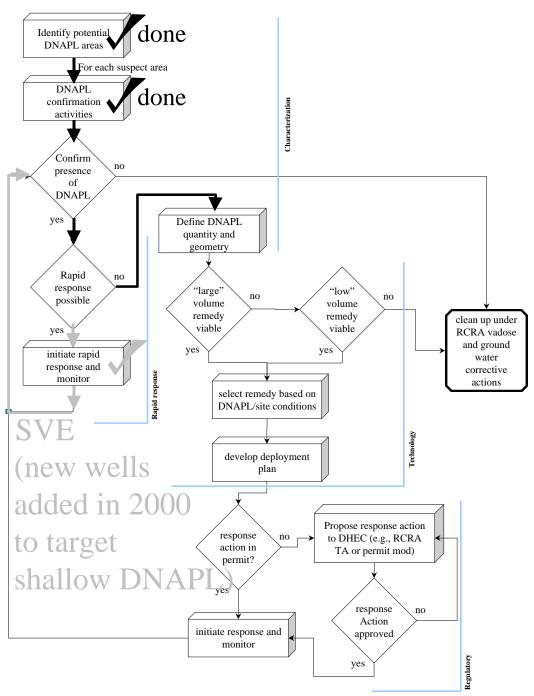


Figure 7.13. A/M-Area DNAPL Strategy applied to the A-014 Outfall

#### 7.2.3.5 Swampy Area on which Building 321-M now sits

Before construction of M-Area there was a draw or depression that passed beneath 321-M and then turned northward past 320-M and thence northwestward. One of the first operations of construction in 1952 was to grade the area and fill in this draw. Thus extensive earth moving equipment was employed. After operations in M-Area began a ditch drained the vicinity of 313-M to the back of 320-M and then to a low swampy spot where 321-M was built. When 321-M was completed in 1957 a drainfield was installed that discharged to the south and west of the facility but most drainage was still to the natural draw over the head of which 321-M had been built (Marine and Bledsoe, 1984).

The swampy spot where 321-M now sits is a potential DNAPL site because it was a drainage area for 313-M and 320-M as identified in Marine and Bledsoe and because building 321-M now sits on that location. This area will be characterized per the characterization of building 321-M (see Figure 7.8).

The drainfield installed when building 321-M was completed has undergone limited characterization. During the 1990 soil gas investigation, six soil gas probe locations were sampled and 1 vapor extraction well was installed with soil samples collected. The results of the soil gas probe shown concentrations of TCE ranging from below detection limits to 7.6 ppbv and of PCE ranging from 0.12 ppbv to 45 ppbv. The highest soil sample concentrations were at elevations of 270 ft msl and 268 ft msl (100' and 102' bgs). The concentrations were 300 ppb TCE and 197 ppb PCE at 270 ft msl and 828 ppb TCE and 663 ppb PCE at 268 ft msl. (CH2MHill).

#### 8.0 FUTURE PLANS AND SCHEDULE

Table 8.1 summarizes the status and proposed schedule for all of the currently identified suspected and known DNAPL source areas.

Table 8.1. Future Plans and Schedule for A/M Area DNAPL Activities as Part of the A/M Area RCRA Corrective Action

	Current	FY 01	FY 01	FY 02	FY 02	FY 03	FY 03	
STORAGE AREAS	Status	activities	decisions	activities	decisions	activities	decisions	Comments
321-M Solvent Storage Tank	h/4	ح	1	(c&d) or (X)	(c&d) or (X) (2) or (none)	tpq	tpq	Dynamic Underground Stripping (and Hydrous Pyrolysis) currently underway
Rail Storage Area East of Building 313-M	Ø	q	1	(c&d) or (X)	(2) or (none)	tbd	tbd	Work conducted in conjunction with Building 313-M (Use Area)
Drum Loading Area South of Building 313-M	Ø	q	1	(c&d) or (X)	(c&d) or (X) (2) or (none)	tbd	tbd	Work conducted in conjunction with Building 313-M (Use Area)
713-A Central Storage Facility	В	q	1	(c&d) or (X)	(2) or (none)	tbd	tpq	
	Current	FY 01	FY 01	FY 02	FY 02	FY 03	FY 03	
USE AREAS	Status	activities	decisions	activities	decisions	activities	decisions	Comments
313-M (Slug Manufacturing Facility)	a/b	Ω	-	(c&d) or (X)	(2) or (none)	tbd	tbd	
320-M (Target Manufacturing Facility)	Ø	q	-	(c&d) or (X)	c&d) or (X) (2) or (none)	tbd	tbd	
321-M (Fuel Manufacturing Facility)	Ø	Ω	-	(c&d) or (X)	(2) or (none)	tbd	tbd	
305-A	Ø	Ω	-	(c&d) or (X)	(c&d) or (X) (2) or (none)	tbd	tbd	
773-A (SRTC)	Ø	q	-	(c&d) or (X)	(2) or (none)	tbd	tbd	
Lower 700 Area (777-10A)	В	q	1	(c&d) or (X)	(2) or (none)	tbd	tbd	
Upper 700 Area (703-A)	b/1	×	none	×	none	×	none	DNAPL not confirmed, no additional DNAPL program activities planned
	Current	FY 01	FY 01	FY 02	FY 02	FY 03	FY 03	
SOLVENT DISPOSAL AREAS	Status	activities	decisions	activities	decisions	activities	decisions	Comments
M-Area Basin Process Sewer	c&d / 2	р	(1) & (3 or 4)	tbd	tbd	tbd	tbd	rapid responses to date: SVE, installation of horizontal wells, in situ air stripping, in situ bioremediation, 6 phase heating and RF heating.
M-Area Basin	c&d / 2	р	3 or 4	tbd	tbd	tbd	tbd	rapid responses to date: SVE, installation of horizontal wells, in situ oxidation using Fenton's Reagent, and hydrophobic lance. Evaluating possible DNAPL treatment of vadose zone and shallow groundwater beneath and adjacent to original basin location.
M-Area Process Sewer to A-014 Outfall	b/1	×	none	×	euou	×	none	DNAPL not confirmed, no additional DNAPL program activities planned
A-014 Outfall	c&d / 2	þ	3 or 4	tbd	tbd	tbd	tbd	rapid responses to date: SVE and recent DNAPL targeted modification to SVE.
7-								

Key:

Activities.....

a = identify potential DNAPL source areasb = DNAPL confirmation activities

c = initiate rapid response d = define DNAPL quantity and geometry e = select remedy based on DNAPL and site conditions

f = develop deployment plan g = propose respnse action to DHEC h = Initiate DNAPL specific response and monitor X = no further DNAPL actions planned, clean up under RCRA vadose zone and groundwater correction actions tbd = to be determined, depends on prior year results

Decisions ........

1 = Confirm presence of DNAPL

2 = Rapid Response possible

3 = Large volume or low volume remedy viable

4 = response action in permit or response action approved tbd = to be determined, depends on prior year results

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### Appendix A

**Core Descriptions and Logs from FY 2000 Drilling** 

## Field Geologic Log

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	2	·	5		7.5 YR 5/9 Fine - V. CORRED WITH	
	3	* \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	ว		Sand 85% STranbin 7.54RKA TO	
	. 4		9		To fine made occasional granules	Sampled ( ) 241
	5	===	18		Clares sand smelin to send the Co	1
13	6	274			Clary sand gooding to send the Co 25-5, 5Trans bro 7.5 485/8 To re 25-8, 4/8, Several Prick copy (amine	
	°	10	ζ,		present strambers, fino - course	
	7	= =	2			
	8	<i>:</i> : ; ;	3			<u>,                                      </u>
	9	10	6			5anple10/29
	/30					
	1					
			/ 3		Sand, 958, red 2.5/R 4/R, Fine-m	ed.
		~~				
	3	1	5			
	4		3		Claversand Clay 252 day and 2	E Y D .
14	5		مرا	50	Clayersand Clay 25% drk red 2	514
	6	خــنــ	5	l	Sand, 95%, wellow 10787/K. Fire course, thin claser zone at 135.7	
	7	1/7				
	Ì	{\/				
	8	1 X				
	9	/\ <u>{</u>				
	140	<b></b> / \			•	
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Project								
/ / / / / / / / / / / / / / / / / / /	4/M DN	APL	14	5°	Angle Boring Location Basin	Date 3/5/00 Drilling Subcontractor	Sheet <u>8 of 12</u>	
Well Nur	mber $m R$	s- 2	9		M. Basin	Orilling Subcontractor		
Logs Pre	Shaled DA	Say A			lr.	Triller	1	
Company		w.				M. Coleman  Drilling Method  Rolo soni c		
<b>1</b>	Depth	T 7	_			Kolo Soni C		
Tan Number	Below Ground Surface (Feet)	Lithology	Percent	Power	Sample Description		Drilling Comments/Remarks	
14	40	X			see above			
	1		2 5		Sand, 95-9970, bynunish a	ellous 104RAFF,		
	3		9				sayla e 1431	
15	4		6					
	5	:	1	60	1		- 101/14	
	6		S				52mpk @ 146	
1.	7	, ,	3					
	8	\/				**************************************		
	9	łχ						
	150	$\left  \cdot \right $						
	1	1213		_	Sand, 85-90% Mc//Ams /7	'R7R		
	2		2		V. fine - grandes with occasion	Jelebles.		
	3		7					
1,	4		ß	75				
16	5		53				Sangle 1551	
	6	. ,	13				sand 136.51	
	7		2.7		7.5765/6 COCKE - V. COO NO	strong des.	sigle 158'	
	8		3		Fig. mod. This 17 gras	El-y Tamina		
	9	$\mathbb{N}$						
	160	X	L			•		
		-					·	

D							
Project	A/m	DN	AP	L	145° Angle Boring Location M-Basin	Date 3/5/00 Drilling Subcontractor	Sheet 9_of_12
Well Nur	mber M K	25 2	29		M-Basian	AFT	
Logs Pre	pared By	غد ۸	100	n.h	ester	Driller M C-	2 m + 4 l
Company		JS R		•		Driller M. Cold. Drilling Method Rotos	·rijav
友	Depth		1	<u>.</u> 1		K0/05	ONIC
Fun Number	Below Ground Surface (Feet)	ппаоду	Second 2	- Page 196	Sample Description		Drilling Comments/Remarks
16	160-	$\nabla$		70			Continues
16	1	$\triangle$	Ш				
17	2 3 4 5 6 7 8	· · · · · · · · · · · · · · · · · · ·	6 0 5 1 0 0 14 2 1	<sup>a</sup> o		siand v. comes,	Sample 2 (66)  Sample 2 (68)
18	1		15, 38 /77 16, 20,	50	Silly Sand Sill 12 dk mallow virtuar med . Several v. Thin soft, 1fl. and brownish soud at 174, vira-fine	d bem 10483/4,	171.5, Sangled @ 173' Sampled @ 15'
	8 9 180	$\bigvee$			7	•	

Project							
Project	A/M D	MAP	. [	45	Location Basin	Date 3/5/00 Drilling Subcontractor AEJ Driller	
Well Num	MRS-	29			M Basin	Drilling Subcontractor	
Logs Prep	ared By	v No	٥w	ke:	tex	Driller M. Colem	an
Company		W5	R	2		Driller M. Colem Drilling Method RoToson?	12" core
Fin Number	Depth Below Ground Surface (Feet)	Uhdagy	Percent	Footery	Sample Description	.0,000,	Drilling Comments/Remarks
18	180	$\nabla$		50	Seeahava		
	1			-	Sand, 952, STrong bore 7.54R	11/1 To	
	2		0		procuresh wellow 1086/8. Course Oreding To fin - V. muscovite Several 4.7hin	COOVSO-IL	50mled C 182
	3		30		Muscovite several v. Thin	It gray Clay	
19	4	==	170	1			Sample P 184
'	5		285	50			Samplade 175
	6		mt				
	7	\					
	8	$  \bigvee$					
	9	Ĭ					
	190	$ / \setminus$			7.50		
	1		_				
	2		22		sand, 9570, 5Trong here 7.	Fine - coase	
	3		kø.		grandes several VIII A		Sampled @ 1921
	4		20		Isminan present		Sample 193'
20	5			70			·
	6		20	1			Sample 18197
	7		20				
			20				
	8	1	1				
	3 H	1 X					
	200	<u>/                                    </u>		_		-	

Project												
	A/M DI	WPL	$\angle$	4	so A	rale E	Bosins		Date 4/7	Jocontractor	Sheet	of 12
Well Nu	1718S-	-29			-	Location /// ~	Basil		Drilling St	Ibcontractor AEI		
Logs Pre	pared By	Ly No	nn/	ke.	stec				Driller	M. Col	PMAN	
Compan	ws	RC					·		Drilling Me	ethod Rotoso	130	core
Number	Depth Below		E	нý	7.0/8>0				<i>////                               </i>	0010		
2	Ground Surface (Feet)	ППабаду	Percent	<b>1</b> 80	Sample Description					Orilling		
20	200		25	D	Sec	See above					Comme	nts/Remarks
$\mathcal{L}$	1	X		<i>[6</i> ]							Samo	2015
	2				S-4	Chay Ch	ayeyse	nd To Sai	dy Clay		0	
		· · · ·	93			INREL	18 w. T.	-11 be	mada S a	-/	5- 0	1 1 1
	3	5	60			MAYS &	4.74	some V.	cours a	Fina.	Samples	209/
	4		71			CCATI	4-1 8	eanules.		-		
ا ۱	5	-	25	100								,
77	6										Sampled	202 .
	7		6								Sampra	-01
	8	7.	10									
	9	_ •	36								Sayled	2091
	210		279		Cave	y Sand	8 7.5	RSR. o	70 504	d	S 4 /	210"
		/ 4 "	24		4.7L	9 1940/	es				C. 0.	4114
	'	-	55			y San	d ci	as 15%	redd	ish	Jany Lane	217-
	2	-	200		bain	L5 08 4	ed ad	a with a	had- U	COALSE	Samphod	2/2'
	3	-	240	1	Deb	il ma	<del>-&gt; =</del> ×	ar Jes a	SEA	4 4	Sampled (	2,3
	4	~ .			Sam	43170	9. v-	ldish ve	Non 7.	5YR6/8	sample	2140
22	5		92	100	11:7	L up.	te not	Win V	Fring -	Eine	Sampled	0 2/5-
	6		V 36		æT.	2184		ndant de			sampled	0216-
	7		138	1	med.	iz co	987	very cl	yeller ean n		sampled	217-
	8	ļ.,	100		pyes	en I					Sampled P	2180
			150									219-
	ľ		30								sampled	249
	220-		٥ر	L								

Project	<del></del>						
Well No	A]m	DNA	P)	اما	FYOD	Date 4/7/00 Drilling Subcontractor	12 of 12
1	MRS	3 29			Location M Basin	Dritting Subcontractor  AF. T	
Logs Pr		. Noc		ء بل	star		
Compai	าง	WSI			2128	Driller M. Colem Drilling Method Rotoson?	an I
1	Depth	T	Rotosoni	1/3"Cove			
Fin Number	Below Ground Surface (Feet)	Liftdagy	PH Sept	Footery	Sample Description		Drilling Comments/Remarks
22	2260		30	100	See above		
23	1 2 3 4 5 6 7 8 9 7 7 D 1		000000000000000000000000000000000000000	100	Sand 75-85%, and Chy?  denver brownish selline  V. Role over strakely Trace  V. f. no-med, at 224 grad.  Cotron Sand, V. Coasse & g.  Near 225  Sandy Clay grading To Clay  85%, Thinky landed talone of  gray, red 2.57R 4/k, and  Clay, mainly It gray with  Camer of sand red and lex  lamine industral  grading To Classes Sand V. Pel  anica, V. f. no-med V. Pel  anica, V. f. no-med	Clay (5% -  Sychow, 17.	5 - sale 23/
	2 3 4 5 6 7 8						7.D.

Project	1/1				, , , , , , , , , , , , , , , , , , , ,	I Data	Sheet		
Well Nu	A/M	DN.	Q F	<u>'ሊ</u>	FYOO / Flute	4/10/00	of		
	MR	<u> </u>	<u> </u>	<u>_</u>	Mbasin	Drilling Subcontractor			
<u> </u>	عر المالية	y Noc	<i>\\\\</i>	ke.	ster	Driller M. Co. Drilling Method ROTOSOMIC/	le man		
Compan	y u	) 5 R (				3" c.ove.			
ž	Depth	>-	П	>-					
Fin Number	Below Ground	Liftalogy	Percent	ğ					
Z =	Surface	ΙĔ	Æ	Ä			Drilling		
u	(Feet)				Sample Description	Comments/Remarks			
i i	o	-	0		Sandy Clay Clay 7590 Y	of IORYR			
		-	١٥		with some reddish cel	Jan mothing			
1 1	1	-	0		Fire- U. coarse, hard - V. hard.				
		<b>-</b>							
	2	*****		l					
		-	١,						
1,1	3	- ·	15	100		····			
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1	4 —	:		l					
	<u> </u>	1:5	15	ļ					
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	· _	:	1	<del>                                     </del>	5-1-61-61-259	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1			
	8		7		Sandy Clay, Clay 75%, 400 */dd/ - Libra mottles Vohard, from U. CON granules present	1884/8 W.Th			
	9	<b>-</b>	2	1	Valored &	- 100 m			
		1			even les oreset	C3 C WILLY	8-10 111		
	/ o		Þ۵			·· ······	Sample 151		
1 1	.,,,	]	``	ĺ					
	1	] : 😓	20		Desse motiling of Blu	e white			
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1	<u> </u>			1					
	3		14						
	ļ	—y .*.	١'	1					
	4	<b> </b> ;	15		Clas (60%). Coarse	ad less			
	<b>├</b>	· · -	'/		Clas (60%).		•		
j l	5	1	_						
	-	-	4	1			sampled P17		
	6	┪╴┷		1	<del> </del>				
		1	7						
	′⊢	1 '.	l'			· · · · · · · · · · · · · · · · · · ·			
		1	<del>                                     </del>	t	Clayer Sand, clay 20-25	2			
	8	17:5	3	1	4/8 Some yellow and a	red 2.5TR			
	9	1	ł	111	Trace of museavite, fi	- Challes			
3	J 7		-		Fining down To a V.F.	CORVED			
	2	]	5	1	muscovite increasing				
	2 1	<u>  • •                                  </u>							

Well Number  MRS 30    Cocation   M Basin   Drilling Subcontractor   ME   M. Cale man   Me   Me   Me   Me   Me   Me   Me   M	Project		<u> </u>						Date	Sheet	
Logs Prepared By  Noonkesta  Driller  N. Coleman  WS RC  Drilling Method  Company  WS RC  Drilling Method  Solver (10/050n/c/3"cole  Drilling CommentarRemarks  Drilling Commentar Remarks  Drilling Commentar Remark	1	A/m	DN	IA P	L / F	INTE			4/10/00	Sileet	2 of 8
Logs Prepared By  Noonkesta  Driller  WSRC  Noonkesta  Driller  WSRC  Noonkesta  Driller  Noonkesta  Driller  Noonkesta  Driller  Noonkesta  Driller  Company  Drilling  Comments/Remarks  Drilling  Comments/Remarks  Drilling  Comments/Remarks  Sample Description  Drilling  Comments/Remarks  Sample Description  Sample Description  Drilling  Comments/Remarks  Sample Description  Drilling  Comments/Remarks  Sample Description  Drilling  Comments/Remarks  Drilling  Comments/Remarks  Drilling  Comments/Remarks  Sample Description  Drilling  Drilling  Comments/Remarks  Sample Description  Drilling  D	Well Nu	mber 100 0			<del>- /</del>	Location			Drilling Subcontracto	r	
Company  WS RC  Drilling Method  Notosonic/3"coll  Below Ground Below	Loge Pro	J// K	<u>S</u>	0		M Ba	51N		I AEI		
Company  WSRC  Dilling Method Rolos Sonic/3"call Below Ground Surface (Feet)  20  7  1  2  33  4  32  5  5  7  35  SITE Sand, SITE 252a, Individual Surface  Sample Description  Comments Remarks  Sample Description  Drilling Comments Remarks  Sample Description  Sample Description  Comments Remarks  Sample Description  Comments Remarks  Sample Description  Sample Description  Comments Remarks  Sample Description  Sample Description  Comments Remarks  Sample Description  Drilling  Comments Remarks  Sample Description  Sample Description  Comments Remarks  Comments Remarks  Sample Description  Comments Remarks  Comments Remarks  Sample Description  Comments Remarks  Comments Rem	Logs	spared by	12	and.	o-ta				Driller M C	,	
Below Ground Surface (Feet)  20  3  4  52  53  54  55  66  7  7  7  7  7  7  7  7  7  7  7  7	Compan	<u> </u>							Drilling Method	mar	
Below Ground Surface (Feet)  20  3  4  52  53  54  55  66  7  7  7  7  7  7  7  7  7  7  7  7	WSKC Rotosoni										10
20	<u>\$</u>	Depth Below	75	- ≥					· · · · · · · · · · · · · · · · · · ·		<del> </del>
20		Ground	ğ.	E 5							
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3			· <u>·</u>	71						-	
3 3 - 8 160  3 2 20  5 20  6 20  7 23  8 25 11 Sand Sitt 257a todinh bro. 225 48 5/4 musicante abundant, 4 2 20  11 10 20  12 20  12 20  12 20  12 20  12 20  12 20  12 20  12 20  12 20  12 20 20 10 2 5/4 To makind 108 5/2  12 20  13 20 20 20 20 20 20 20 20 20 20 20 20 20			·	'						-	
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3  4  132  5  6  120  7  135  SITE Sand 5 IT 25 Pa tedd show to the show the show the show that the street of the show t		2		1 4	w			·		<del></del>	
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30 7 35 S.IT. Sand, S.IT. 257a, 1 26/3 A BTW.  2. S.IT. Sand, S.IT. 257a, 1 26/3 A BTW.  2. S.IT. Sand, S.IT. 257a, 1 26/3 A BTW.  2. S.IT. Sand, S.IT. 257a, 1 26/3 A BTW.  30 77 10 10 10 10 10 10 10 10 10 10 10 10 10	12			11							
30 7 35 S.IT. Sand, S.IT. 257a, 1 26/3 A BTW.  2. S.IT. Sand, S.IT. 257a, 1 26/3 A BTW.  2. S.IT. Sand, S.IT. 257a, 1 26/3 A BTW.  2. S.IT. Sand, S.IT. 257a, 1 26/3 A BTW.  30 77 10 10 10 10 10 10 10 10 10 10 10 10 10		4	' , '•	32						san	-elad e 24º
30		<u> </u>	-	2.5	ļ		<del></del>			_\	
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Sitt Sand, sitt 259a reddishbow.  2.54R5/4, muscavite about the street of the street o											
Silty Sand, silt 257a, reddishbow,  2.5 1/8 5/4, muscante abundant  u.fine-file  10  11  10  20  30  70  11  10  20  31  31  41  41  -2  5  6  -1  19  8  6  -1  19  8  6  -1  19  8  6  -1  19  8  6  -1  10  10  10  10  10  10  10  10  10		7		35							
30 17 18 STRS/4, muscante abundant, water 129  20 Trade into Claser Sand weak red 10R5/3 water coarse  4		<del>  -</del> -	¥	$\vdash$		· ·	212		44'		
4  30  10  10  11  10  20  31  31  41  41  41  41  50  10  10  10  10  10  10  10  10  1		8		1 1	7-5	PR 5/4	5,77 2.	5.70	- In . A BYW.	<del>-</del>	
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4  4  5  6  7  19  8  Claver Sand Clay 2020 weak Year 10R5/2, muscarite presen		'		16					· · · · · · · · · · · · · · · · · · ·	<del> </del>	
4  4  5  6  7  19  8  Claver Sand Clay 2020 weak Year 10R5/2, muscarite presen		2	]·	20	7/2	dias in	tocla	2 Ly Sa	u weak		
4  4  5  6  7  19  8  Claver Sand Clay 2020 weak Year 10R5/2, muscarite presen			<b> -</b> "		req	10 85/4	1 70 0	make he	d 1085/3		
5  6  7  19  8  C/axex Saud Clay 2020 weak  Yed 10R5/2, muscante presen  you fine coasse with excession 1  granwer some gellen matthing	1,	3		1	14.E	- co			-		
5 6 7 19 8 C/aver Sand Clay 10/0, weak red 10/25/1, muscarite presen year coarse with excession I granuler Some gellan matthing	17	<del>ا</del> ل ا	,	1 1							•
5  8  Claver Sand Clay 10to weak  red 10th 5/1, muscovite presen  year lowers a theresia l  granuler some gellen matting			<b>1</b> – _	2							
8 19  8 19  8 19  8 19  8 19  9		5		$\lceil \rceil \rceil$							
8 19  8 19  8 19  8 19  8 19  9		I	٠ , ١	10							
8 Claver Saud Clay 20% weak  Year 10 R 5/2, muscarite presen  9 11 100 V. fine Coayse with excession I granuler Some gellow matthing.		6	┨	]"	-		-				
8 Claver Saud Clay 20% weak  Year 10 R 5/2, muscarite presen  9 11 100 V. fine Coayse with excession I granuler Some gellow matthing.		_	1		1						
5 grander some gellen matting.	L	」 '⊏	<u> </u>	19				******		<del>                                     </del>	
5 grander some gellen matting.		8	٠٠٠٠	8	C/0	wey San	d Cla	y 202	o weak		<del></del>
5 sander some gellen matting.		-	2.		red	10R-51	12 mi	Scari	te presen		
	5	9	17.5	'	14.74	COE					
] <del>[ [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ]</del>		1 ,,		3	8~4	-WEI	<u> </u>	20110	· · · · · · · · · · · · · · · · · · ·	<del></del>	
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	5	9 4/0			14.74	- coa	Y54 4	The	ccasia.		

Project						Date	Sheet	
	A/n	1 DA	MI	PL	/F/UTe	4/10/00		
Well Nur	mber MRS	- 0	וב		JFIUTE Location M Basin	Date 4/10/00 Drilling Subcontractor		
Logs Pre	Poared By	- >	0		M BASIN	A E I		
""		- 11	•	JL.	estex	Drilling Method  As To sovic/3" cose		
Compan				V( \(\)	SOLEY	Drilling Method	na N	
L	Depth	<u> RC</u>				13 care		
🛓	Depth Below	중	=	ج				
Ju Number	Ground	Ufictogy	Percent	ğ				
듄	Surface (Feet)	5	=	Œ	Sample Description		Drilling Comments/Remarks	
	40		H		se e above	77.11.11		
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		-	2					
3	2			100	Sand 9070 yeddish be	N 54K5/4,		
-	3	31	1,		U.F. ne - med			
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	5							
1	6	•	3		reddies became v. This bon	till be		
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	7	l ' :						
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	8		ا دا		Claver Sand yrading To S	andy Clay		
	9	-	'		ciny 90 20-60 heak with strong bear mothing	red / DK 5/2		
	-		12		Fine-med Firm Land	A SAY / NO.		
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		111	''	l	Fine - med. with gran	3 XX 6/8	· · · · · · · · · · · · · · · · · · ·	
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	7├─		40				Sampled e 571	
<b></b>		<b>  •••</b>	۳	┝	Sand. 952 A. 1+ == AN			
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5	9	] ::		١	with secssional granule	<u> </u>		
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Project					In-t- IO	
	A/m	DNA	1PL	FIUTE Location M-Basin	Date #////OO Sheet #/ of 8  Drilling Subcontractor AEI  Driller	
Well Nur	mber MR	5-3	<b>ת</b>	M-Basin	Drilling Subcontractor	
Logs Pre	pared By			1	Driller	
Company	,	NOON		7e <sub>Y</sub>	Drilling Method	
	u	USRC			M. Coleman  Drilling Method  Rotosonic	
Fin Number	Depth Below	8	F 5			
<del>Z</del>	Ground Surface	Liftdogy	Percent Fectuary	County Develop	Drilling	
<u>"</u>	(Feet)	•	<del>-</del>	Sample Description	Comments/Remarks	
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Well Nur	A/M	DNAI	<u>"                                    </u>	FIUTE  Location		4/11/00	_5_of_8_
	ma	253	Q	M-Ba:	SIN	7/11/90 Drilling Subcontractor AEI	
Logs Pre	pared By	J. Noc	wke	sta		Driller M. Co	leman
Company		J. No.	-			Drilling Method Roto:	leman sonic/3"core
Fun Number	Depth Below Ground	Lithology Percent	Ž.				
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Project	A/m	DNAP	LJ	F	1UTE Location		Date 4////OO Drilling Subcontractor	Sheet
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Company	<u> </u>	~00	v K	es	/ex		Drilling Method	eman puic/3"cose
	Depth Depth	SRC		_			Rotose	Nic/3"Core
Tun Number	Below Ground Surface	Liftdagy	Fercent Fercent		Sample Descr	iotion		Drilling Comments/Remarks
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Project						Date	Sheet
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Well Nur	nber ha a c	2 -			Location (A)	Drilling Subcontractor	
Logs Pre	MRS pared By			_	M Basin	Driller .	
	Ja	y No	on	ıkı	ester	M. C	oleman
Company	y ·	SRC	_			Drilling Method  RoTosoni	124 000
<u> </u>	Depth					K01020701	C/3 CO(42
Jin Number	Below Ground	Liftdogy	Percent	[ ]	7		
Ē.	Surface (Feet)	5	82	<u> </u>	Sample Description		Drilling Comments/Remarks
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1),	3		78	184	Very dry No maisting	T = 11 . 12	Samplade 123'
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	5		58	į			sample 1251
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	<u> </u>	<del> </del>	-		Sand 9570, reddish Me	1/04. 7.5YR 6/8	Samplede 178'
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Well Nur	nber A/h	<u>n D</u>	AVA	PL	FITE Date 4/11 Location Drilling S M Base w	ubcontractor	8 of 8
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Logs Pre	pared By		1/		1 1	n Coleman	
Company	y		000	1	Drilling N	M. Coleman lethod	
L .	Depth Depth	SRC		_	<i>R</i> .	Tosonic / 3'	'core
Number	Below	⊔fhdogy	Percent Promeny	7		· .	
<del>Z</del>	Ground Surface	QE I	28		Sample Description		Drilling
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		7.7.7	7	_	med, - v. coaist.		
	8	<b>.</b>	204	1	Sand, 98%, brownish yellow	240-10	1481
	9		409		Vitie + med. Many U.Thin-	Thin-	1491
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Well Nur	nber	~/ ~	N	<u>/</u> E	Drill ~ 45°   Location   A - 14	3/27/00 Drilling Subcontractor	<u> </u>	
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Logs Pre	Jay Noo.	J.Kar	t	,		Driller M. Coleman Drilling Method Rotosanie/3" core		
Compan	v				· · · · · · · · · · · · · · · · · · ·	Drilling Method	7 ** '	
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			ľ		Firm-hard, soul mod - v. coal	se		
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Logs Pie	J. A						Driller M. Cole n	1 00 01
Company			7-0	-,,	- 8		Drilling Method	
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	3	**1	'	ĺ	SofT_	,	, V. TIM - MESK!	
	4		8	ļ				sampled e 44'
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Well Nun	nber		~/	<del>,,,,</del>	<del></del>	Location			3/27/00 Drilling Subcontractor A E I		
	Pared By	<u> 32</u>				A-14			A E.I		
	J.	Noo	νk.	es 7	éx				Driller Coleman  Drilling Method		
Company	ws								Rotusonie/3" Cose based		
<del>  _ ,</del>	Depth			_					1 401820016	3 Cole Morel	
Fun Number	Below Ground Surface (Feet)	Ппаоду	S S Percent	o Fecouery			Sample D	escription		Drilling Comments/Remarks	
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Project	A/m D	NAPL		A	agle Drill 45°	Date 3-27-60 Drilling Subcontracto	Sheet
Well Nun	mbér MRS	-32	7		Location A-14	Drilling Subcontracto	or .
Logs Pre	pared By					Driller	
Č	<u>J.</u>	Noon	Ke:	Ter		Drilling Method	eman
Company	•	WSRO	۲_			RoTosonic	
Fin Number	Depth Below Ground Surface (Feet)	Uflalogy	3 GPercent	Se Facouery	Sample Description	Drilling Comments/Remarks	
8	80	X		80	sce above		
9	1 2 3 4 5 6 7 8		230 1000, 2000	80	Clayer Sand, Clay & 30, band of Yeldish rellow 7.5 YR1/8, pale yellow, medicaaxce  Sand, Clay & 10, multicals  rellist gellow, Strong bran, for White medicul coarse, po grane 185, Soft  Clayer Sand, Chay & 25-30;  The goarse-med with  I sand granules, coft	STrong bray  Firm-SofT.  35/maTI/sol  At /t bray  consisted	Sampled @ 83'
	1 2 3		000000		Sand, 95-98 %, Strong PEN Med-coasse with many Occasional grandes; one grand Clay landing at 21.5	Thin Latt	
10	5 6 7 8		0 00	50			Sample 10. 96'
	100	$/ \setminus$					

Well Number   Magle Drill 45   Date   S-27-00   Sheet   G of 11    Well Number   MR S 32   Location   Drilling Subcontractor   A = 1    Logs Prepared By   Driller   Driller   Mr. Cole Mar    Company   WSRC   Drilling Method   Drilling Method    Below   Ground   Gr
Company  USRC  Depth Below Brund Surface Sample Description  Feet)  10  Stand 92-32 brannish ellew 1074 fk  med - V. coarse with amisgal  3 resists and same plants  4 resent user rand of run.  Samples 108'  Sampl
J. Nooskester  Company  USRC  Depth Below So Town Surface  (Feet)  Sample Description  Sample Description  Drilling Comments/Remarks  To Sample Description  Sample Description  Drilling Comments/Remarks  Sample Description  Sample Description  Drilling Comments/Remarks  To Sample Description  Sample Description  Sample Description  Drilling Comments/Remarks  To Sample Description  Sample Description  Sample Description  Drilling Comments/Remarks  To Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Drilling Comments/Remarks  To Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Drilling Comments/Remarks  To Sample Description  Sample Descr
Dolling Method Rotosomic / 3" carle  Below Ground Surface (Feet)  10  Sae above vertical depth - 70.757.  Sample Description  Sample Description  Drilling Comments/Remarks  Sample Description  Drilling Comments/Remarks  Sample Description  Sample Description  Drilling Comments/Remarks  A sample Description  Sample Description  Drilling Comments/Remarks  A sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Sample Description  Drilling Comments/Remarks
Depth Ground Surface (Feet)  10  10  10  10  10  10  10  10  10  1
Sample Description  Comments Remarks  Sae above vertical depth - 70.757.  Sand Arish, brownish allow 1044 fft, med. Vacarise with armisqual greades and same publies of 108', 2-7 V. Thin the gray class leaving present near rand of run.  Sample D 105'  Sample D 1
Sand Ross, bransh allew 10x8 f/k,  med. V. coaxse with armisage  greates and some peoples of 108',  2 - 2 V. Thin Marry clay Jamine  present near radiat run.  Samples 10s'  Marry Clay 12mine  Samples 10s'  Samples 10s'  Samples 10s'  Marry Casy Sand Clay 25, bracenist yellow  2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2
Sand R-253, braunish gellew 108 4k,  med - V. coarse with armisage)  grandes and same peoples at 108;  2-3 V. Thin /h gray clay 19mins  present near and at run.  Samples 0 105;  March - V. coarse with zones of
med. V. coarse with amisgal  y  grendes and some peoples of 108',  2-7 V. Thin Hyrax Clay Ismine  present wear and of run.  Samples 0 105'  Med. V. coarse with 2000 5 of
3  3  4  5  6  7  6  7  10  Slayer Sand Clay 125, brownish yellow  2  10  10  Slayer Sand Clay 125, brownish yellow  2  10  10  10  Slayer Sand Clay 125, brownish yellow  2  10  10  10  10  10  10  10  10  10
present near radat run:    Sampled @ 10s'   Sampled @ 10s
Sampled Q 10s'  Sampled Q 10s'
Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Market Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Market Sampled C. 108'  Market Sampled C. 108'  Market Sampled C. 108'  Market Sampled C. 108'  Market Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Market Sampled C. 108'  Sampled C. 108'  Sampled C. 108'  Market Sampl
Sampled C 108'  Sampled C 108'
Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'  Sampled C 108'
Sampled C 108'  Slayer Sand Clay? 25 brownish relland  OYR L/R and gellandish hrm 107R 5/B,  med-y cases a th zones of
Stayer Sand Clay 1, 25 brannish yellow  2  110  2  110  110  110  110  110  1
Stayer Sand Clay 1, 25 brannish solland  2  10  10  10  10  10  10  10  10  10
Slaver Sand Clark 25, hearwish yellow  2  10  10  10  10  10  10  10  10  10
Slayer Sand, Clay 2, 25, hearwish yellow  2  10 YR 6/8 and ne How ish bro 10 YR 5/8,  med - y, coax se with 2000 of
O Slayer Sand Clay? 25 hearwish yellow  2  10 YR 6/R and ne Howish brow 10 YR 5/R  med - y coarse with 20005 of
O Slayer Sand Clay? 25 hearwish yellow  2  10 YR 6/R and ne Howish brow 10 YR 5/R  med - y coarse with 20005 of
2 MARCH and yellowish brow 10 YR 5/8,
3 granules several zone of Thin
12251 Se Mand Se Add 1/1/
÷: 10 65
12 5 Sagle 0 1/8'
6 Sampled @ 1/6'
7 Sampled @ 117'
8

	COLUMN TO THE REAL PROPERTY.									
A/m DN	IN PL	1 A		lo D	cill 4	150			Date 3/28/00	Sheet
nber Mos _ 3	22		<del></del>		Location		Drilling Subcontractor	•		
pared By	,					, ,				
J. Na	ouke:	ster	-			Drilling Method	Man			
WSRC	Depth > >								Rotosonie/	13"core
Depth Below Ground Surface (Feet)	Liftdogy	Percent	H-coner y			Sar	mple Descript			Drilling Comments/Remarks
120	$\bigvee$			Sce	above					
1		Ш								
2 3 4 5 6 7 8		0.00000	50	Some of med	/ 902 - coax - / y a y C k	3-752 158, 26 150, 25 150, r>150 150 150 150 150 150 150 150 15	brausis 1250	56.	clew 10 YR 48, caxse vera) v. Thin	Saylo/p. 125/
1		000000000		pelu Clay Yest watt	Sen 2. SYR	4/8 m	Jan úta:	Sen	d, clay 25%,	
	3. No.  y USRC Depth Below Ground Surface (Feet)  12.0 1 2 3 4 5 6 7 8 9 13.0 1 2 3 4 5 6 7 8 9 9 7 8 9 9 7 8 9 9 7 8 9 9 7 8 9 9 7 8 9 9 9 7 8 9 9 9 9	Depth Below Ground Surface (Feet)  12 0  1  2  3  4  5  6  7  8  9  13 0	Depth Below Ground Surface (Feet)  12 0  1 1  2 3  4 4  5 6  7 8  9 9	Depth Below Ground Surface (Feet)  12 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	J. Noonkester  USRC  Depth Below Ground Surface (Feet)  12.0  1	J. Nowkester  USRC  Depth Below Ground Surface (Feet)  12 0  2  3  0  17  8  9  13 0  1	Depth Below Ground Surface (Feet)  12 0  1	J. Nowkester  WSRC  Depth Below Ground Surface (Feet)  12 0  See above.  See above.  Sample Descrip  Sample De	J. Nowkester  USRC  Depth Below Ground Surface (Feet)  120  Sand 908-752 brownisk  acd - coarse occasion v  And y even 1/25, se  It gray Clay lamines at 1/3  Chyersand grading into sand  brownisk gellies to YR 6/8 us  acd by the and grading to  sand v fine and grading to  sand v fine and grading to  sand v fine and grading to  sand vest 2 SYR 4/8 unth yellow  sand people and people and  sand people and sand sand  sand vest 2 SYR 4/8 unth yellow  sand people and sand sand  sand people and sand sand  sand sand sand sand sand sand sand sand	A/m DARP! Angle Drill 45°  Interpretation of the part

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Project	A/m Dr	MPL	1 A	וצות ל	le Dr.	11 45	-6		Date 3/28/00			
Well Nur	nber				-	Location			3/18/00 Drilling Subcontra	actor		
Lana Dea	MRS - 32 pared By	г					14		AEI		·	
Logs Fie	J. Ne		4	٠					Driller M	<i>t</i> .		
Company			-3/	ex_		Drilling Method ro7050A.1c/3			· · · · · · · · · · · · · · · · · · ·			
	USR Depth	C							rotoson.	'c /3	"Core	
Fun Number	Depth Below	욧	Е	ř						<b>′</b>		
틀	Ground	Uflidogy	Percent	ğ							Dalling	
튭	Surface (Feet)	5	~	Œ			Sample	e Description			Drilling Comments/Remarks	
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Project	41		_			Date	Sheet
1	A/M E	ANC	PL	//	Angle Drill 45°	3/28/00	Sheet 9 of 11
Well Nun	nber MRS- paréd By		•	/ -	Location	Drilling Subcontractor	•
	MRS-	32			A-14	AEI	
Logs Pre	paréd By					Driller	
	<i>□.</i> ~	oonk	es`	16	<u> </u>	12. Colo	man
Company	1 ,, 000	•				M. Co/O Drilling Method	13"core
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i ži i	Depth Below	<b>*</b>	=	는			
Fun Number	Ground	Пповру	Percent	ğ	•		
5	Surface	5	æ	Æ	Sample Description	1	Drilling Comments/Remarks
	(Feet)		١	_			Commentary Citians
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-	1		1	$\dashv$	59ml, 70%, 5 Trong pra 7.5	V07/0 5:	
		**	-		Squel, 20%, Strong bru 1.5	18 3/ B, Fine -	1.
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	3				- Marie Committee		
12	<u> </u>	1., .	140				5auphole 1641
1 4 4	4	===	1		Silty sand . STrong bow 7.5	YR.5/8, V. Fire-	
		]==	30		F Sand 85%		
1	5	]:::::::	Li				sanded 6 165.5
1 1		]`.:.	138	100	Sand, 90% branish reli	on 10/86/8	
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1	· -	2.25	Z	1	Sand, 90% reddish	1/Au 7.58868	
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Project					A .		Date	Sheet	
	A/M	DNA	$\rho_L$	_ /	Angle Drill	450	3/28/00 Drilling Subcontractor	10 of 11	
Well Num	nber	20		-/	Location		Drilling Subcontractor	·	
Laga Dros	MRS-	<u>32</u>			A-14		AEI Driller		
Logs Fiet	T AL	<del>onk</del>	100						
Company			C	10	· Y		M. Coleman Drilling Method		
		RC					ROTOSONIC	c/3"core	
ž	Depth Below	34	+	ιÿ					
Fin Number	Ground	Uftiology	Percent	Š				Drilling	
Ē	Surface (Feet)	5	2	Œ	Sam	ple Description		Comments/Remarks	
	180	₩,5-\$	7		see above				
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Project	A/M anber MRS	DNA 1	92	/A	role	Drill &	50		Date 3/28/00	Sheetof
Well Nur	mber MRS	-32				Location A-/	<i>#</i>		Drilling Subcontractor	
Logs Pre	pared By	Noo	nk	esTe	?``					Man
Company						Driller M. Cole.  Drilling Method  Fotosonic			13"000	
Fin Number	Depth Below Ground Surface (Feet)	Ufidagy	Percent				Sample Des			Drilling Comments/Remarks
20	200		0	100	ser	above				
	1 2 3		6 0	Z Z 2	Said Link J. Pa Omo	Clay - C ly hands le box, ; comet	lax-to	Sano C year coldist	ls Clay ledish bellowed Loper, 72: Juk and box,	Sampled 201 Green Clay
21	5 6 7	(A) (A) (A) (A)	6 ·	120	San-	ou to)	R6/2 as	To S L.V.	and brownish fale branches.	Say 206'
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Project	A/M Arc	a 1	MAC	PL/45 Anale Boring	Date 3-29-00	Sheetof/_
Well Nur	MRS	-33	?	PL/45 Anale Bosing Location A-14	Drilling Subcontractor	
	<u> </u>	iy M	JOON	kester	Driller M. Co.	leman
Compan	$\omega s$				Drilling Method Ro 7050	vial 34 core
Fin Number	Depth Below Ground Surface (Feet)	Liftotogy	S Percent A Fectuary	Sample Description		Drilling Comments/Remarks
1	0 1 2 3 4 5 5 6 7 8 9 9		100	Sandy Clay Chy 70%  Foxed 10 R 4/8 with  mothing from 6' to 9',  sand coarse	not 2.5YR 5/8  My 110 w  hand - Firm,	5qup/ed Q 847
2	7 0 1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9	1501年16日,1501年16日	1 0 1 200 2 4 3 4		Sand med -	Sampled 2 15'
3	2	11.1	0 100	SadyClay clay 65-75 Med. 33 no yellow to	thite mothing;	

Project	44 4 1	<b>1</b> 0 €	10 (	))	Location A-14	Date	Sheet
	A/M Are	· PA	WP	1- 1	145 Angle boing	3-29-00	2_of_11_
Well Nur	mber M A	c 2	1		Location	Dritting Subcontractor	
one Pre	///K	<b>3 - 3</b>	<u>&gt;</u>		1-19		
Logs	Jay	Noon	ke	ste	<b>4</b> .	Driller M. Cole	man
Company	ws	or				Intillial Aleginon	(
<u></u>		てし				ROTOSON	<i>''</i>
Number	Depth Below	8	_	ا چ			
	Ground	Liftdogy	Percent	ğ			
一語し	Surface (Foot)	5	عة	Œ	Sample Description		Drilling Comments/Remarks
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1	<del> </del>	; +-	1		Clavey Sand, Clay 20-3	1090, restor	
	8	11.1			4/8 from- soft med.	-coerse	
1	<u> </u>  −	15 4	0		- une strong byw. Malling.	· · · · · · · · · · · · · · · · · · ·	994 NO 29'
<del></del>	9-	-	1	11	Clayer Sand el 20-20-25	c/4 49 Jane	1
	¬ , -		0		Clayer Sound, Clay 20-80%, down, red 2.5784/8 To	MY VOL 2 CYD	Sampled @ 301
	3 %──		2		6/8 uith Model: Lbru.	nothin saw	
	l ₁⊑	] - ' -	1	1	Vifine - ned , hard - fir	A.	***
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	! <u> </u>		8		Sitty Sand sitt 15-257 o It. red 2.5 YRL/8 with m	lecrossin down	
	3	<b>↓</b>	ľ	60	Itized 2.5 YRL/8 with m	Ult color wrist	
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5	40	:	.[9	180	3/6 with many order	calous paleto	(
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Project	4/m DA	19AU		/4	5° Augle   Location   D	Oate S 3/31/00 Orilling Subcontractor	Sheet
Well Num	MRS-	33	7		Location D	Orilling Subcontractor	
Logs Pres	pared By	<del> </del>		1.		riller	
1	J. No	onke	251	les	•	M. Coloma Drilling Method	
Company	NSR					Orilling Method	1211
<del>  -  </del>	Depth			_		roto sonic	13 COLE
Fin Number	Below	Uficial	Percent	ξ			
₹	Ground Surface	Ě	ğ	ğ			Drilling
듄	(Feet)		۵۰	œ	Sample Description		Comments/Remarks
	40		П		and Higyay clay lawing,	Sand V. Fine-	
1	' ' 🗀	ا نـــا	5		med.	. *	
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1 1		ΙX		İ			
	9		6		Study 85% mult-bawale	alue at	
	50	1	1	l	weak rad pale red . radice	L. puisle,	
1	. → <u>`</u>	] 、	1		4 ellow ult some white	sand.	
1 1	1	1	1	1	sever 1 4th 11. gray chy	lamine at	
	<b> </b>	1	0	50	ucok red pale red, radice yellow with some wite sevent with it gray chy 53.5°, sand v. finer med.		sampled & 51'
1 1	2	1	١.	l			
6	·	<b>-</b>	5	1			5 / 10 5 / 2
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1	8	<b>1/ ∖</b>					
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	│ <sup>™</sup> ├─	1:-		.†*	Claver sand, Clay 30-40	2. 011+	<b>t.</b>
18	60	]		10	mainly Steam ben 7.54Rs	18 and	
		] <b>:</b> : :	3	<u>'</u>	Pink SYR 7/U other color	s u lite la	at)

Project	1/10 04:05	21 / 12	1 / 0	, ,	, ale		Date 2/2//00	Sheet
Well Nur	1/M DNA!		:5		Location	<del></del>	3/31/00 Drilling Subcontractor	_ <del></del>
one Dre	MRS-3	3			A-14		A E.I.	
	J. 10	oonk	es	te	<b>Y</b>	ia N		
Company	V	SRC			Orilling Method To 78 Source			/71ºcoce
ě	Depth Below			۶.			10/038200	1
Fun Number	Ground Surface (Feet)	Аборцп	Percent	T. Poole	· · · · · · · · · · · · · · · · · · ·	Description		Drilling Comments/Remarks
İ	60	† T	22		11. reddied bru me	v.1	thin Clay lawing	
	1	-	18		present mainly NEA	s end	ATTUAL FIRM	
_	_ ' <u></u> _				<b>VIII</b>			
	2	- T-	23					sampled @ 621
	3		10					
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	4	- 7.	20					Sampled @ 64'
	5	===	12					
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1	8		9					sampled P 69'
	9		12			·		
			3		Sand To Clayey Sand 15% Clay, Very f of reddish yellon	Fo Sa	d, 1570 - 3076	•
	70-	' ' ' .	.		of radial and allace	ina he	anding Colois	
	1 1	<b> </b> : :	5		med.	7	water, Fine-	
	<u> </u>		11				· · · · · · · · · · · · · · · · · · ·	
	2		7					Sampled P731
	₃⊏							/
8	<u> </u>	<b>↓</b>		95				
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	6	1	-	1	clases send. Clas	252	enellarish	
	7	]	. 3		clases send, Classbra 10 YRS/R, U. 1	Eine - c	gasse, ficm.	
	-	7.						
	8	]: · ̄ _	2					Sampled P 79.
	9	· · · ·	4	<u> </u>				
	<u> </u>	<b>┤</b> ;``:	" ' <i>'</i>		Soul, 95% brown	aird a	cllow 1048 6/8	Sample 1 880'
9	80-	<u> </u>	1 3	دد	COATS!	79.(*		3 = 100 ·

Project			_			
	A/m L	MAPL	./	45	Date 3/31/00  Location Drilling Subcontractor	Sheet
Well Nur	mber MRS~	33			A No. 2     Date   3/31/00	
Logs Pre	pared By					
	Jag	Noo.	<u> ∾K</u>	آک	Orilling Method	an
Company	/ W5	RC			Drilling Method  **Pot > 50%	
<u></u>	Depth		_		T6/250N	
Fin Number	Below Ground Surface (Feet)	Liftdogy	Percent	Hoovery	Sample Description	Drilling Comments/Remarks
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	1 ├─		2		· · · · · · · · · · · · · · · · · · ·	
9	2		y	35		Sampled C 82'
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	├ <u>.</u>	<del>                                     </del>		├	Sand 95% nellow 1088718 and	
	9	1	Z	1	brought sellow 104R7/8 and	
	90	]			and in down To med - U. coasse	
	'	`	0		aith avancles + occasional pebbles	
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1	<b>│</b> ⁴├──		3			
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	6	1.	0			Sampled @ 96'
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	7	<del>                                      </del>	X			
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-	9	<u> </u>	<del>   </del>	+-	Sand, 90-95 la bravaish as llaw 1948	
1,.	,,,	1 : : :			Sand, 90-95/e, brownish no llaw 10 YR (18, med coarse grading To coarse v. coarse millgrandest pebbles	
	100	1::	<u>. sə</u>	L	v. coarse withgrandest peoples	Saplate 100.51

Project	A/m	DNA	PL		us* angle  Location	Date 3/3//00 Drilling Subcontractor	Sheet <u>6</u> of <u>11</u>	
Well Nun	MRS-	33		•	Location A - 14	Drilling Subcontractor  AEZ		
Logs Pre	nared Rv	ه ۱۸ و د		الم		Oriller M. Cole man		
Company	′	ws			- Aller	Drilling Method Yotasovic		
<b>½</b>	Depth		_	_		1076380		
Біп Мимбе	Below Ground Surface (Feet)	Linday	Percent	- Foorery	Sample Description		Drilling Comments/Remarks	
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	1					tour 10486/6.	sampled e 101	
	2		50		LOYR 6/8. Fire - V. Course A	176 granules	Sampled 19102	
1//	3		4	100	several Thingmy clay lan.			
	4 —		94	'~	Sever Thin Thick layer	ow 10486/6.		
	5		1		Sand Same color.	ers of Clayer	Soughat @ 104'	
	,				Clare Co. 125 1 T	6.1		
1 1	6	· - 5.	5	'	Clayer Sand granding To branish gellow 109RL	The med-		
	7	] - [			CORVEY		compled @ 108	
1 1	_	- [ -	9					
	8	1	1					
-	9		8	-				
	110		2		Sand, 85- 95%, yellow 10 med with accasion! V.	casse.		
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12		]	3					
1	5						sampled e 115°	
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	-	-						
	9	<del></del>	1	t	Sand 85% brownisky	ellow 10 YR		
13	120	]	120	1	6/8, some Black sandy	V. Thin layers	Souples @ 120	
L	<u> </u>	Щ	15	1	present Vifine - Coars	e with contin	٠-()	

David A												-		
Project	Am DN	MPL,	14	50	ANgle	2				Date 3/3	1/00	Sheet	of	11
Well Num	nber MRS- pared By					Location	A-14				contractor			***
Logs Pres	pared By									Dellas				
1	2.	Noon	uke	esta	ચ					14.	cole mo	111		
Company	WSR	C								Drilling Me	thod Tosowi c	/3"c	ost.	
- I	Depth	_	<u> </u>									<del></del>		
Fin Number	Below	ППООДУ	S Dercent	ξ										
💆	Ground Surface	₽	₿	ጀ									Drillin	ıa
&	(Feet)	_	NO.	لج			Sa	mple Descri	otion			1	Comments/I	Remarks
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Project	A/m D	MAR	. / 4	45° 0	n= )a			Date	Sheet
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P	MRS pared By	33			A-14			AEI	
Logs Pre	5.	Now	keste					Driller M. Cole	nan
Company	ws	RC		-				Drilling Method	/2/1 - 242
ا تد ا	Depth	·		1				101030116	73 2016
Fin Number	Below Ground Surface (Feet)	Liftedagy	Percent Facouery			Sample Desc	cription		Drilling Comments/Remarks
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	<b>"</b> □		, 71						
	4		<b>'</b> 9''	540	7 0.1	1.011	1420	7/0 6'	Sampled @ 144
	5□		10	70.00	<del>24 , 78/6 ,</del> /	- MELLOW	7078	7/8, v. Fino-	sampled e 146
	<u> </u>								
	6		2						
	_ _	$\Lambda$	11	-					
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	8	1 N							
1 1	_	{/		-					
	9	• • •	20	Sa	nd, 90-	9590. ST	rons	brn 7.54 R 5/8	
	750	1	5	4.7	M. some	live mot	11/2	brn 7.57 R 5/8	
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17		┧`∷	`   ,	D 70	Mellou	salvad i	7 R 4	16 Fine-med.	
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Project						1= . T		
'	Alm	DNA	PL	14	Location	3/31/00	Sheet 9 of //	
Well Nun	mber MRS pared By	33		•	Location A-14	Drilling Subcontractor		
Logs Pre	pared By	- AL	_	. 1	ester	Driller		
Company	<del>,                                    </del>				23 185	Drilling Method  to To S ONic/3"COSE		
- T	Depth	WS	_			1050 No	c/3"core	
Ju Number	Below Ground	Liftalogy	層	) get				
Ē	Surface (Feet)	5	S Opercent	Y POOPEN	Sample Description		Drilling Comments/Remarks	
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	7	]	ľ					
	8	<u> </u>	]		Claver Sand Clas 35-462	settid sellar		
	9	F. 5-	ľ	H	7.54R 6/8, Fire consist.	1/au 7.5786/8.		
	170		0	<b>'</b>	Fire Viction avadin to	POTES - U. COLINE	Sampled C175'	
			10		with occasion granole	7.		
	2	<b></b>	5					
18	3		13	110		a clayey	Sampled 0 1741	
	4	7.5	,		SELA C/2/9:H 20-258	STrong JEN		
	5		6		Fig- Vicare occasion	1104 7.5 886/8		
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	<u> </u>	]; <del>-</del> :	٦					
	7	<u> </u>					sampled@ 177'	
.	8	<u> </u>  3.;	. 1					
	. 9	1: 4:	4	1				
	180	<u> </u>			tand(0-0140) clay's ilt (20-4	10%) strong ben		
L	/6	1		$\perp$				

roject	- 1				Date	Sheet		
	AM DNI	9PL /	45	Angle	4-3-00	<u>/ 0</u> of _//_		
Vell Nur	nber			Location	Drilling Subcontractor			
1	<i>MR5-33</i> epared By			A-14	AEI	1		
					Driller	-		
No	nkester/3	me s			Michael Cal	eman		
Jompan	y				Drilling Method			
1	NGC Depth				Rotosonic	13" core		
<u>ķ</u>	Depth	>-	_ >-					
Fan Number	Below Ground	Liftdogy	Percent Peccueny					
걸	Surface	I≝I	ξX	_		Drilling		
Œ	(Feet)	-	- u	Sample Description		Comments/Remarks		
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	l <u></u> ⊨	<b>├</b>	l			Sampled 186.52		
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i	l			Sand formed, sighth with, in stoney brown & It gong; trace mis to >10mthick)	Herlaminated_	<del>  , , , , , , , , , , , , , , , , , , ,</del>		
	190-	-	1	strong brown 3 It gray; trace me	ca (laminae)mm	sampled 190-5'90 164		
20	ļ <u> </u> -			to ziemthick)				
""	1 1-	<b>∤</b> ∶∴:	100			sampled 192.0 PED 198		
l	<b>!</b> ⊢	<b>-</b>	/*	sand fining down ward to An	= rifn.			
1	2	-	Ì			Sampled 193.0' PED 112 gan		
1		1::::		trace mica				
	3	<del>-</del>	I	sittement microsing				
	-			SPT & day, inter laminested be	coun & H. gray			
	4 —	1						
		4 ::::		Sand 100 to med-cre, mod. so	oted, white to			
	5	<b>↓</b> ~∵.	1	Brongbown		50mg/al 195. 2 PED 17.00m		
	1 -	1-,-		change lamine (22mm thic) 20	<del>-</del>			
1	6	∵.	1	-				
1	1 L	<b>∐</b> - ` · i	1					
	7	J •	1	coarse gramed stong from son	d 5 YR 8/8			
		"։	1	tr. mua		Sampled 198.0' PIDIZAM		
1	8	<u> </u>	1	Gand (40-60%) G. H. Clay (40-60%)	interlaminated	1 1		
		J <del></del> Ξ−.	.1	come brown changing in inter	claminated some			
L_	_] e	<u>-</u> -	[	from the red 18h. 5 that red gra	mules			
		_ <del></del>	1					
2	200	]	-[	Color painaciles H. Sime and 11	OVB/I w/sed & br-	sampeda 200.0'		
Ĺ		]		Color primarily H. Sintagray 15	d	PLD Ham		

Project				Date	Sheet				
	A/m DNA	1214	150 6	tucle 4-3-00					
Well Nu	mber			i rocation in initial subcontractor					
	moer → MR5 epared By	-33		A-14 ON Fall AET					
Logs Pre	epared By			Driller					
w.	3ones			m. column					
Compan	y			Drilling Method					
5	RTC			Calverne	Rotugonic				
	Depth	>-	<u>&gt;</u>						
Fin Number	Below Ground	Liftalogy	Percent Ecovery	·					
Ž	Surface	ÌĔ	¥ &		Drilling				
Œ	(Feet)	-		Sample Description	Comments/Remarks				
	700	<del></del>		Clary 260+ (40-60%) fine cand (40-60%) +race	***				
i	1 20°		1	mica, It obinegram 104 8/1 w/ sed & borner					
	1			language 2 mm to 7 mm thick					
	i ' 🗀	<del></del>		THE THIRD THE THIRD					
21	2	1	į.	tough clay (~80% dig)					
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	_			10x2 76 1 10 x2 8/2 for cos					
l	6	1- :		1016 40 4 70 4 8 B/ 2 FR- 45					
1	l .	<u> </u>	1	soud content increasing down ward	3000phd @ 206.0'				
	7	1::-		The content increasing and warely	PED 27 April				
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	mR	5 34	¥		A-14 Wester	AEI		
Logs Pre	pared By				) /	Driller		
		Jay	N	201	ikester	Drilling Method Rotosonic/3'cock		
Compan	v	-				Drilling Method	1 ) 11 .	
	uske					KOTOSON	10/3 Coll	
Fin Number	Depth Below	8	7	~				
§	Ground	Liftdogy	Percent	ğ				
🖟	Surface (Feet)	5	8,	ŒΙ	Sample Description		Drilling Comments/Remarks	
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l		s	0	ll	a Clay Sand at 15.5'	Sand Coarse		
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1	6	]	١,					
1		l.~/	16					
	7		0		Clayer sand or maling in To	sitty sand		
1		1	1	1	c/ax/5:17 25% red 10	OR 5/8 To	Sangled P 18'	
1	8	<b>↓-</b> ,	28	1	15. red 2.518 6/8 U.F. u	- med, gmli		
3	1 ⊢	<b>∤∵</b> ∸		100	To V. Fine File	· · · · · · · · · · · · · · · · · · ·		
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	2.0	<b>1</b> .7≒	. /33	ľ			sampled 20	

Project						In a second	
	Alm	D N.	API	L	FYDO	Date 4/13/00 S	Sheet 2 of 8
Well Nur	mber MR	5 3	4		Location A-14	Drilling Subcontractor	,
Logs Pre	epared By	A/	<u></u>	JL.	estor	Driller M. Col	1. mas
Compan	V				00771	Drilling Method	' : 211
<u>ا</u> ا	Depth Depth	RC		_		ROTOSONI	'e/3"core
Fin Number	Below Ground Surface	⊔ħdogy	Percent	E SOUR			Drilling
<u> </u>	(Feet)		po '	-	Sample Description		Comments/Remarks
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	1	-	24	-			
	2		55				Samplede 22'
	3		26	100	Sand, \$ 85-75% incre	sting dame	
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	4		57	ŀ			
1	5	]	74	Ī			
Į	6	٠. ا	20	ł		•	11 26'
		<u>                                      </u>					
	7		0		Sand, 85% + e-H-5h. A 6/8 and It sed 2.54R6/9	e/lou. 7.54K	
	8	-	a		med. WiTh a coasiand V.	coarse, several	
		<b>*</b>	42		Thin Clax lamine present.		Sampled @ 19
ļ		-1.5	7	100		multi-coho	
4	3 0		47		and many other colors Fi	vellow, pink	77 3/
7	1	] " <i>•</i>	13		with granules ad occas	ind pebbles.	
		- 6	1			·	*# 33/
		]-:	17			·	
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5	* _	] ::'		88	several sandy Clay lan	inas present.	
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Project	Alm	DN	AP	<u>,                                    </u>	FYOO	Date 4/13/60 Drilling Subcontractor		
Well Nur	nber M K S	- 24	1		Location A-14	Drilling Subcontractor		
Logs Pre	pared By	. No	ענפ	k	ester	Drilling Method  Adosonic/3"core		
Company	ď	RC				Drilling Method	c/3"core	
Tin Number	Depth Below Ground Surface (Feet)	тробил	Percent	T TOOMS	Sample Description	Drilling Comments/Remarks		
5	40-		9		see above			
	2		12					
	3	==	25	<b>5</b> 0			Sampled C 441	
	5	$\bigvee$					Stappet C. 44-	
	6							
	8		0		Chayey Sand To Souly Clay of Dale red 2.5/ 6/2 with a colors in Thin bank it in - m. Thin pale red Clay laminar	c/ay 10.30-10, many other med, several		
	9	-	0		Thin Alexad Chy low new	present menty		
	5 0		5	100				
6	2		8		Sand with clayer sand 17 4 = 11 mis bear 104 REP	1 zones		
	3 4		13		Mannish relland lot Ref	Fire-coasse		
	5		-					
	6 7	10 E	3	-	Claser Sand, Chy 302	17. bon 7.5786	4	
	8		10		Claser Sand, Chy 30% and It redict box 5486/4, with accession grantes		Sampled C 58'	
7	9		5		Jand, 90%, redishber 7.5	42.54R5/4 4R6/8, Fine-		
- [	6 %	∃ : ։	: 0	1				

Project	A/m	044	D,	<b>+</b>	Y 20					Date	2/00	Sheet	4	of <u>8</u>
Well Nun	nber	UNIT	7		100	Location				Driffing Su	3/60 focontractor			<u> </u>
	pared By	34	ŧ			A	-14				(EI			
19	. 14		***	koc	tex					Driller	n Call	2 (41 01 11		
Company	' wsk	<u> </u>		<del>/</del>	<u> </u>	<del>*************************************</del>				Drilling M	M. Colo	ZMUZ		
	Depth			_						Ro	to sonic	$\frac{1}{3}$	( C &	66
Number	Below	Ппаоду	Percent	₹										
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R 30-27# (2-	-12-97)			Field	Geologic L	₋og			
oject ell Num	A/M ber M.C.	ON	HPL	FYDO Location A-M		Date 4//3/03 Driffing Subcontractor	Sheet		
gs Prep		Jay	Noc	ukestes		Driller M. Coleman  Drilling Method  Rotosonic / 2" core			
mpany		WS	RC			Rotoson	ic/2" core		
Fyn Number	Depth Below Ground Surface (Feet)	Lindogy	Percent Peconeny		Sample Description		Drilling Comments/Remarks		
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Project	1/4	ONIO	(0)		[V n =	Date 4//3/00 Drilling Subcontractor	Sheet <u>6 of 8</u>
Well Nur	nber /	PIVN	TL.	<u> </u>	Fy Do  Location	Drilling Subcontractor	
B	MRS	34			A- 14	A&I	
Logs Pre	pared By	a N	<b>~~</b>	,ke	ester	Driller  M Cole	- A.
Company	wi		<u> </u>			, rid v	
<b>-</b> 1	Depth			_		5/3" core	
Number	Below Ground	Liftdogy	Percent Percent	7			
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	ı "E	<b>1Λ</b>					
	6	<b>//                                   </b>		ŀ			
	7	<del> </del>	6	ヿ	Sand, 70%, reddish A	gellow 7.54R	
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	6	$\Delta$					
	7		9 0		Sand, 900, seddish	xallow 7.54R	(k)
13		1 3			H. gray Clay laminas	al U. Thin	
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Project	A/M	DNAF	ト	7	FYO	8		Date 4//3/00	Sheet		
Well Nur	nber	5-32				Location		4/13/00 Drilling Subcontractor AEI			
Logs Pre	pared By	>-5 ~	<u> </u>			A-14		Driller			
	Ja	<u> 200 x</u>	۸,	<u>ke</u>	stek	W-5-4-4-		Drilling Method Rotosonic/3"cole			
Company	ν	USRC						Drilling Method	onie/3"core		
jer	Depth Below	8	Ξ	ح							
Fin Number	Ground Surface (Feet)	Ufidagy	Percent	Ž.	Sample Description				Drilling Comments/Remarks		
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1 -		$\exists : :$	10	١,	9-	di to co	erse with g	randes and			
15	8	٦٠.٠		100	100	babes.					
			/6	İ					Sanple 1391		
		] . — .		1	Sam	in Chart	o Clay, C	Lay 85%.			
	140	4.4.1	10	1	7/1	N/V bard	C 0/045 #T	neeldish			
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Project	A/m	DN	AF	0/	FYON	4/13/00	sheet
Well Nun	m A	2 سك	34	7	Location Dr	rilling Subcontractor	
Logs Pre	nared By				in.	341	
Company	,	Noo		<i>(e:</i>	57 <i>o</i> \$	M. Cole	man
	L	USRO	<u>_</u>			ADTOSON,	c/3"core
聲	Depth Below	Ą	11	щý			
Fin Number	Ground Surface (Feet)	Uflology	Per Series	Rowery	Sample Description		Drilling Comments/Remarks
-	/4 o		Н		and STrong how said mad-		
	~~ <u>`</u>		5		11. Good clay fra ,40-14	12' Sails	
١. ١	1				Clay above and belo		50 mpl 142'
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		7.2	30				144/
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#### Appendix B

Daily Activities from FY 2000 Drilling

Project A/n/	ΟλιΔΟ	1. Characterization	,	
		L Characterization	Dining Cabcontractor	
M. C Well Number	oleman	Technical Oversight	A É I Oversight Firm	
Well Number	. a a	Technical Oversight	Oversight Firm U) 5 RC	W.
Location ///	- 4	J Woonkester	Date	Page ,
M S	espage	basin	4/4/00	of
Start	Stop	1	Description of Activities/Remarks	188
8:00		Drillers 1 over	sight of location	Setting up
20-		ON MRS-29 SKIPPAN ER-24, 1		
8:30		SK: Plan ER-24, 7	lefirst grane usel, he	s been moved
* ,	<u></u>	to basin but	nas not emptical.	I have paged
		Theron Twice	Toting out The	deal, but he
12:00		7 7 7 7 7 7	I Fletchor Brown.	and e-mailed him
72.9		The west to for	The SKIPPAN . The	y are disposition.
	-	aceta ako	maiting on a p	len Desportation
		we start drill.	m. Should aros	a = ro / 1:00
2:00		First sun 4-11ft	we have This po	mand station To
		drill.	· ·	
430		Drilled 714T	Today Fletcher L	Davis Eans by.
		He is try's	odicide houts	Ladle FK 1 pan
	=	ER. 24.		
	5:00	+		The second secon
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Technical Oversig	nt Signature	In Wort	Date	4/4/00
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Project K / M	DALA D	L FY00	,		
Driller			Drilling Subcontractor		
	Cole m	an	I AEL		
Well Number Technical Oversight  MRS-29 T. Noorlester			Oversight Firm		
Location		T. Noonkester	Date	Page 2 E	
M	1 Basin		4/5/00	Page 2 of 5	
Start	Stop		Description of Activities/Re	marks	
7:30		wasmuptruck-	ald- 320.		
		Driller's started	2 830 (Dr:11)	79-5	
76100		Dillers take by	cak 97 16:00	-/Smins.	
11:00		Drillers mix	in hatel at	10 00 de 10 10 de 10 17 15 de	
		difficult. over	sinh to	ger, william garres	
12:00		BablassusTa, E	Ruste Margani	X and Fletcher Davis	
		smalled SKipp	en then pun	Tot at 10:00. gel, driving detting  And Fletcher Davis  and custer off	
2:30					
2130		Frech pickely	SKIFFAN	and harded it	
2145		drillris brok	e doun: 29	ens weed replacing.	
		127 Nov. 111 day 100 A	والمساحدة	of an il Kildata	
		will order p.	arts from of	marain A we	
-	4	the parts - 1) b	e here in The	marain -1 we	
	4:00	Finished	579	or drilling by buch time.	
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Technical Oversig	ht Signature	Ja Hand	_	Date 4/2/0	
50.00		Ja lent		Date 4/5/00	

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Project /	ha DAIA	DI EYDA			
	M KNA	PL FYDO			
Driller M	Coloma	ر <sub>ا</sub> ا	Orilling Subcontractor  ### A F I		
Well Number	Tribute in the second	achnical Oversight	Oversight Firm		
MR5	29	Nechnical Oversight  J. Noonkesta	EUSRC		
Location			Data / /	Page	
M-E	Basin		4/6/00		
Start	Stop		Description of Activities/Rema	arks	
8:00		Quersight on		***************************************	
		Drillers not L	ant f.		
9:45		Trolled S. Rive	ler for update	and be inid aget	
	·	to the total	10:00 t- 1	To Distil	
				en Drillers will	
4.1.2.3			x To job site-		
11:00		prillers are on		aking repairs,	
		1 esterday I	sent analytic	results on	
		The other A-	14 skip pan to	Fletcher Davis	
		This mornin	I cell fletcher	-14 5011	
		results are		Y and day	
		To SKIP Pan		To m- Basin.	
1:30					
,,,,,	-	Skip Pan has	arrived Rep		
		goon. Show	H be ready to	s drill at	
0.0	ļ	2:30-7:00	• • • • • • • • • • • • • • • • • • • •		
3:10		Repairs comp)	ate and tested	Prillers mixing	
		another bate	L of mud to luk	casim.	
3:40		Drilling To 171	NOW YUN#17.		
		Firshed you t	77		
	4.13	Para de la companya d			
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Alm	DNAPL	- FYOO		·
			Drilling Subcontractor	
///.	Colem	Technical Oversight	AEI	
		Technical Oversight	Oversight Firm	
MRS Location	29	J. Noonkester	WSRC	
Location	I amin	145 Angle	Date 4/7/00	Page
///	645IL	173 ANGIE	1 4/ 1/00	
Start	Ot	*		
730	. Stop	0:11	Description of Activities/Re	
870 870		Willers and GV	rsight on locat	196.
8.4D		water Truck ay	-ALIA -	
8'55		Profite m it	rig or red con	wests untime.
9:10		The hard can retain	broke and has	400 = S.
11:00	<del>                                     </del>	On 11 = 12 15 1/1/	house trackle of	drancin corebarel
		more vade hout	com Mixing 3	h-Tokes of and
		with hope ?	Lieudel holp. u	e has drilled El
		So far This mor	W. I kon .	
11:20		Deillor had to he	ce casing Te	advance Through hand
		sea - train ! . I sending	hine a Toppen!	Take 1711
1300		Finished run &	up run #22.	Dilling is stores.
1525		Drillers pullin	Up run #22 3	211 - 221
1550		Figial coming	ue have not fin	istaliet bot Briller in soit uill not wek on Manday.
		will pull out	several 6" casi	in so it will not
	430	be stuck who	n we come be	ck on Manday.
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Technical Oversi	nht Signeture		<u>,                                      </u>	Data
Todalineal Cyelsii	Aur olduarnia	Jan Moonkes	<b>k</b>	Date 4/7/00
L		you worker	<i>y</i> -	- 1 1 - 5

Project	M DAL	PL FYDD		•		
Driller	70 107	11- 1100	In.	rilling Subcontractor		
Dniler M.	Colen	Technical Oversight		AEI		
Well Number		Technical Oversight	lo-	versight Firm		
MRS 2	29£30	J. Honkester	İ	WERC		
Location		5 - Ande bosing	Di	ate 4/10/00		Page _5_ of _5
, ,	,					
Start	Stop			Description of Activitie	s/Remarks	· · · · · · · · · · · · · · · · · · ·
7:00		oversist + 1	Drillers	na location		
7:30		I Talked to	Joe R	ossiba abor	JT16.	NOXT boring
		whose we	NIII PU	T The NAPL	- Ribba	Next becing
		TOTYYTOG Went To	25 70	110' Tad	law.	
10:00		11,00 -7 7-	0.5	. To Emi	1 Yeh.	esults from
10 (20		7.	<del>(                                    </del>	1 0 2 1000	. / <u>.</u>	Q 0//G 1/6~
		SK'p pase (	FIEL	edge Links		
12:00		hit.	ong to 7	ed, 221-2	231, C	ree Clay was
2:00		Sypettin 3nd	aulli.	· C'entina	140	oullal so far
2.00		11/61/00	201	7 7 / Jave	been pe	110 out Prillors
		are wow b	reaking	down pl	attorn	oulled so the Med out Prillers Pley built
		32 bass of	grant a	used in This	Lale	
		130 haas 05	ed in	M RS 31		
		30 6095 439	ed in	MRS 32		· · · · · · · · · · · · · · · · · · ·
4:00		Set un an	1 dx:bla	on MK	<u>5- 38</u>	
41:15		-   ダノハー様 / ハー・	7.51 11	25 St. 1500 many	. 40,0	Field sexsening
		shawed 3	<u> </u>	-7 ese	- 100	rus inthe
		- Wan heat	ed cor	e cecising	FAISE	reading. Ushnuy
		A SI NOT	Acre	50 7, CO	2. H	T some
		Jakony -	J47	brong 31	mpling	KIT Pole-ve
ļ		with me	- se	had to 1e	ave	<del></del>
	5:30	Cove 67.5.	<u> </u>	ed To desc	ribe 2	runs in the
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Technical Oversi	Aur Sidustrie (	a Non los			Date	4/10/00
L		The Moon state	<u> </u>			4,1-1,00

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nuer .			Drilli	Drilling Subcontractor		
/// .	Cole ma	<u> </u>		relabit Firm		<del></del>
	Te	chnical Oversight	Ove	rsight Firm WSRC		
MRSZ	29 k 30 3	T. Monkester				lo
ocation M B	esin/45	Date	4/10/00		Page of3	
Start	Stop		D	escription of Activities/	Remarks	
7:00		oversists &	rillera	on location		
8:33		T Talked to.	INE RO	sib~ about	- Tle 1	voit boring
		whose we n	.711 <i>Pu</i> 7	The NAPL	Ribba	in i dee soid
		TOTYYTOO	TO TO	110 Toda	٠.	
56;61			CE CO	TO Emil	Tab y	esults from
		Extono. Th	FIFT	Low Davis		
12:00		run # 27 c	motete	1,221-2	7/1 C	ree Clay was
		らナ.	0			
2:00		grouting and	aullia.	6" casine.	140' 4	Med so far Med out Prillers
2:00	1	11/11/11/11	2012	71 Laure	are PL	Med out Prilbes
٠.٠٠		are your by	en bina	down pla	Ttorn	ney built
		32 hags of a		sed in Thick	10	
	<u> </u>	30 bags Us		n RS 3 1	41E	
****		- J	4 3	7 RS 32		3.5 //45
4:00		30 60 5 USe	-(x: b/1 in		- 38	
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41:15		runtil, 0-7	13, 10	Or second		
		showed 2	o pph	-/		reading. Johnson
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		a s s Not	Leve			Kit taleare
	<u> </u>	Jakony -			pling	-A'/ 70/E-4
	1	with me	, re	d To lesur	Ve -	4 +1-
	5:30	Coce 67.5'.		al / & ACSCY		runs in The
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Technical Overs		a Non bas			Date	4/10/00

Project	I/M DI	VAPL FYOO		
			Drilling Subcontractor	
[// ,	Colem	Technical Oversight	AEI	
Well Number	30	Technical Oversight	Oversight Firm	en en en en en en en en en en en en en e
I ocation		J Noonkester	Date	Page 2 2
<i>^</i>	1- Basi	~/Flute	4/11/00	
Start	Stop		Description of Arthetics (Down	
7:00	Stop	Drillone	Description of Activities/Remark	irks
7:00		Jac Rossiba		- location. They
		will deals	Flutte membrene	in MRS 30 6" casin
	ļ. <u></u>	have done	sector bricks for	Carland Joe.
10:00		Ton Kexitz +	Sinkupy strong by for	a 15 mil visit
12:20	ļ		47.5' - 157.5' 15 40	
	1	Tagged bot.	of hole at 161.2	TO TOC
			ground surface 2-10	7.8
· · · · · · · · · · · · · · · · · · ·	<del> </del>	From ground	BUNGLED TO BAT. OF	hale 158.4'
2:30	<u> </u>	Joe 6 C	oth conduct 157.5	Flite
	1	John Brade	stoped by to so	rekta Tac He !-
		EK Kearlos	S Team.	13/10/00/10/23
	7:00	The Flute C	and out	***
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Project	IM DAY	APL FY 20
Driller /7		1 Unling Supcontractor
	· (DIEN	nah AE+
Well Number	34, Te	NAL AET  chinical Oversight  Oversight Firm  USRC  Date  Dat
MK:	5 29/30	J. Noonkesteb WSKC
Location	/	Date 4//2/00 Page 3 of 3
MBA	Sin	1/12/00 rage 3 of 3
Start	Stop	December of Ash May Demodes
12:28	Stop	Description of Activities/Remarks  Orillers never weith or me which I arrived at ARS 30
		This man my They grouted holes while I
LZD		was in Distrity Training.
p.30		AT A-14 looking Ex Next location.
3:00		Set up on MRS 33
	275	ready to start drilling in morains
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Technical Oversi	ght Signature (	Ja Monto
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Project	. ^	11001 -/ 4	. 4'		
Driller A/M	Area Ul	VAPL Character	azelion	·	
M's	Lad Cal		Drilling Subcontractor		
Well Number	Te	/ E Man chnical Oversight	Oversight Firm		
MRS-2	132	J. Noonkester	WSRC		
Location A -/			Date	Page / / /	
71-7	7	1	3/24/00	raye of	
Start	Stop		Description of Activities/Remarks		
7:30	ļ	oversight at 1	Demo Trailer. Prill	er are to arrive	
\$:3 <u>\</u>		at 8:00.			
9:00		Prelab briefing	a detail		
11:00		The tie & all c	sompleted asim trods decon location at A-1:	N. read	
11:00		set upon first	location at A-1	Y. R.S. is	
-		Setup and 45	augle has been	determined	
11:20		Colne a /EVe			
17. 20		To build Play	oving the site to p	sick up material	
1:10			I with plywood &	2×105 To build	
		plattour.	ve will not any	Tomassan (Fri)	
		because Kasen		of here cithes.	
****		hos a Dr. app	ne medical has ex	m 50 we usuld	
		pot set = let		Breare v. +	
		gains Tostart	Today but will 5	Tast morday	
	4.33	maraine wete	_ /\		
	2:30	Prillers Done	2 For the day		
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Technical Oversigi	ht Signature	1			
Tracinical Oversigi	n Signature	3 Hooker	Date	3/3/00	

Project A/N	1 Area	ONAPL Character	ization	
Driller 1		,	- ming outpoonstation	
Mich	rel Co	leman	AEI	
Well Number		Le man Fechnical Oversight	Oversight Firm	
MR5-3	4	T. NoonKester	WSRC	
Location A-/			Date 3/17/00	Page 2 of 4
Start	Stop		Description of Activities/Rer	marks
7:23		oversight on 1	see tion alegaria	re papel work,
7:45			A /A / AL	
8:00		Karen Vangares 57	gally and gave	me a message Ta
		45 363 h = Cone	er sile of it first	3, 3-3/83 page
ī		concerns shad	t the power line	Talled add
		Pased him an	Can you wait	to for him Tereture
		Tail!		
8:3.0		Dave Harver co	me down and	oxadus to prill
9.40		and Signed of	For ucp	****
9:40 9:50		cunt 1 , 11fT	7+7 vecovery	
7.50		reaking. They a	ger la med po	on sealed a litis
		pick up 7"casin	The comment week	7. h
11:00		Doilles back o	site and ober	7" 55 54
11:40		fun 2, 11-21 f7	100 % recover	
12:00		YUN 2, 11-21 FT	100% recovery	
2:15		ne one non at	91 FT. Orillare	left site to pick up
71.00		porepipe.	Ext. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.	
3:00		Core was boxed	1/2 UITL & BRI	5/ <del>2-5</del> ·
4:00		Finished For 76 d	7 ron 0 - 51.	
		18.37.4	•>	
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Technical Oversig	ht Signature.		·	Date (
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Project A/M	10	JAP/ ) -	· · - 41			
Driller	NYEA D	NAPL charact	Drilling Subcontractor	Y: 201/ 0		
Miss	had Co	Technical Oversight	A £ T Oversight Firm			
Well Number		Technical Oversight				
MR 5	32	J. Noonkester	Date			
A-/	4		3/28/00	Page		
Start	Stop		Description of Activities/Remark	ε <b>(S</b>		
7.30		Oversight GI	location			
8:15 7:00	· · · · · · · · · · · · · · · · · · ·	Diller's arrive				
11:00	<del> </del>	SUN# // Fier	t run roday			
12:30	*****	J. Live T Abase	stopped by for a visit	-/ +/		
12.50		27 /7:00	as 1811 18 9011 6	LOWISHY CLASS		
		Orillars Land	mixed up beston	to mud because		
		drilling in T	Itin difficity	we are at 161		
		FT of Hagle	Will The lost w	un (run#K)		
		had un higher	hits on PID. The PIL	peggal		
	<del> </del>	several Times.	All samples rece	well yell dots to		
1 7 111 0	<del>                                     </del>	Indiate To	y had high truet	s of containtes.		
12:45		are reparin	o is plugged with	sof containte.		
4:00	<del></del>	constitut be	· Ducky ·	770		
4.30	430	finish for the	day			
		1.6.3.				
	,	74.00				
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Technical Oversi	gnt Signature	Le Honter	Date	3/28/00		
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Project A/M	DNAPL	Characterizati	64	*
Driller M	chael 1	Tallo Man	Drilling Subcontractor	
Well Number	- inco	DIE MAIV	Oversight Firm	
Well Number MR5-3	32\$33	Technical Oversight  J. Noowkester	100546	
			Date	Page (1 1)
A-	14		Date 3/29/00	of
Start	Stop		Description of Activities/Rem	arks
8:00		Drillers on los	cation and beginn	in to grout.
8:30		Pick up co	with Rust at ba	dec office. She
		15 901 Te	cation and beginn writing Rust at ba Take samples f	or her mostors at
		430.	- i	عارت المراجعة
		Total death me	sterday was 211 -t 43	12111 = 149.4
1:30		Chiatin Rust 1	est site at 10:30	
1:50		Drillers Lave	pulled all cas	in and wouted up
		The bose L	ole Alaw sette	ing and wouted up
.,		77783-72		
3:00		PITHEYS TYPSE	Tup and ready To	STEVT drilling
3:20		che ked The a	usle on drill rows.	anditis at 450.
		acceptly sen	in a little should	tode The 450.
	430	finished con	pleted run 3 To 2	9 f T ·
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Technical Oversig	nt Signature	Jes New 1	<u> </u>	ate 3/29/00
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Project 1/M	DNAP!	Characterization	K	
Driller M	. /	Character 12011	Drilling Subcontractor	
Well Number Technical Oversight			t Dilling Dubcolluation	
Well Number		Technical Oversight	AEI Oversight Firm	
MR5	32\$33	J. Noonkester	WSRC	/
1		3 : 1000 x 100 t	Date	Page &
Location A-	14		3/29/00	of
				-
Start	Stop		Description of Activities/Remar	ks
8:00	<u> </u>	Drillers on loc	ation and beginn.	TO GYOUT MRS32
8:30		Pick up Chi	riting Rust part band	ge office - Sho
	<del> </del>	15 900 70	Take says for fo	TO GROUT MRS32  ge office - Sho  y her thostory at  delarist Diggle
	<del>                                     </del>	usc.		aciar a regiae
1:30	<del></del>		storday was 211 -t 45°	. 211 = 149.4
1.53	· · · · · · · · · · · · · · · · · · ·	Christile Ruel le	AT SITE AT 10:30	,
··	*	Dr. ICYS A A P	pulled all casi	and grouter up
	<b>-</b>	MRS-32	le. Nous settin	pen
3:00		Distler Tres	Tup and ready To.	at it will
3:20		Che-ked The a	wile on drill rooms a	L'+ CATUA
		acreelly sumi	ma little sholls	WAT TIO YES
	430	finished -com	oletal run 3 To 29	<i>f</i> 7.
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Technical Oversi	ight Signature	0 11 5	l Date	
		Jes Mento	S   Oat	3/29/00

Project A/N	n DNAF	L Characterii	lation		
Deltor			Drilling Subcontractor		
111, Coleman			Oversight Firm		
Well Number  MRS-33  Technical Oversight  Tay NoowKestex			Oversight Firm		
11145-33 Jay NOONKESTEY			WSRC		
	1-14		Date 3-30-00	Page 2 of 4	
Start	Stop		December of Astulking (Demoder		
7:30	- Glop	0015:-154	Description of Activities/Remarks	// by	
7.50	<b>-</b>	crip Truck drive	should arrive soon	To carred a say	
	· · · · · · · · · · · · · · · · · · ·	To mos 22	10 cation. Johnny	Rind or collect	
	·	10 11123 80	of the Prilleren 1	T TV	
		CAT	This mounty and	t would not	
		CHIT	The until are	7 20172 003	
		MAYANT	to the state of the	5 50,30,00	
	1		et to stand to may but of vain.	any nay because	
		•			
9:00	<u> </u>	M. Calana	· lacation . Skip o	Portar Kaluston	
	1	Arres To to	e strip on To Make	22 / 10 / 10 / 10	
	<u> </u>	To rail	- 32.7 pm., 13.111.5-	11. Peginalas	
	9.30	Azined out			
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Technical Oversi	ght Signature	1 -1-1	Date		
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Project A/M DNAPL Characterization					
Driller  M. Coleman  Well Number  MR5-33  Technical Oversight  J. Noon Kester  Location  1-14			Drilling Subcontractor		
M. Coleman			A E I Oversight Firm		
Well Number Technical Oversight			Oversight Firm		
11162-	<u> </u>	J. MODUKATER	WSRC		
Location A-14			Date 3/31/00 Page 3 of 4		
Start	Stop		Description of Activities/Remarks		
230		Oversialt and	ocation. Oxillers on location		
9:30		1 number 4 70-39			
9:30		consisted the se 79'- 89' willow for I Some has be			
		et 7:00.			
10:30		Kim Wierbicki	Chris Berger and Ton Kindle stapped about is mins.  169 FT. Drillers and mixing much be came of The othern said we are		
400		by to vist # 50	about 15 mins.		
1:30		we are down	· 169 FT. Drillers are mixing mud		
		in wow.	recommended to the the sand we are		
2:00	3:00	Finished.	New York Control of the Control of t		
3700	3.00	7/2/3/			
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Technical Oversigi	ht Signature.		Date . /		
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Project	- i 1					
<i>A-14 4</i> Driller	5 Hrgle	•	15.00			
			Drilling Subcontractor			
M. Cole man  Well Number   Technical Oversight			AEI Oversight Firm			
			SRTC			
<u>MR5 - 3 27</u> Location	<u></u>	W. Dones	Date	Page		
A-14 Dw	+ full		4-3-00	4_ of 4_		
Start	Stop		Description of Activities/Rema			
0800		Writer & I. S. mmons mite w/M. Coleman & J. Hall, Ir. Watertruck				
		departed site.				
0830	ļ	and there to make come one of the side . Dollanker in the in it is it is the				
	<b>!</b>	Drieting w/ Brigh Sire	briefing w/ Brian Giracke (HEI), diller's belanchenter truckdriver Completed drilling. Drillers deported site to pick upgrout. Drillers returned to site. Skid-pan mover on site.			
11:15		Completed drilling.	Drillers departed site	to pickinggrout.		
12:30		Dollers returned to	osite.			
13:05	<del> </del>	Skid-pan mover	maite.			
13:10	<del> </del>	Wither A gite W/6	cid-pan mover to relocate	ganto M. Basin		
13:25	<del></del>	Wester cothered	baite. Drillers mixing	coment/bentonite.		
15:10	<del></del>	J.S. onsde to samp	e ekippan			
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Technical Oversig	ht Signature		The	ate 1/2//-		
	,	Ja Hoorker		He 4/24/00		
L		- 1-000 MED				

Project	IM DW	APL FY 20	-	
Driller VY	1	· lo	rilling Subcontractor	
Well Number	· COIEM	chnical Oversight O	Versight Firm	
MR.	5 34/30	5. Noovkesteb	WSRC	5
Location	, ,	. D	nto .	Page
M BA	Sin	·	4/12/00	of
Start	Stop		Description of Activities/Remarks	
12:00		Orillers were no	itile or me who	s while I
120		This morning The	y grouted hole	s white I
200	<del>-</del>	AT A DI GASI	ty Training.	
3:00		AT A-14 lookmofor	NexT /ocotion.	
3,00	775	ready To start dri	115 in marria	
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Technical Oversig	ht Signature	MI	Date	11/12/20
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Project A / W	DAIA	DI FYAD				
Project  A/M DNAPL FYOD  Driller  M. Cole man  Well Number  Technical Oversight  Jay Noork  Location			Drilling Subcontractor	Drilling Subcontractor		
M. Coleman			n El			
Well Number Technical Oversight			Oversight Firm			
MAS	3 <b>49</b>	Jay Moork	WERC			
Location A-/4	4		Date 4/13/00	Page		
Start	Ston		D			
8:00	Stop	Oversight on	Description of Activities	/Hemarks		
9:00	<del></del>	Dill To	1000111	1 4 1 6 1		
10:00		Or: 11.	Mase 124 1	rated - beginning To		
10 00			alenan) NotiFlad -			
	1	hay do	a land a land	ned is running its		
		A- 14 - 1-4	all the destant	The state of the state of		
		4-2- 17	will seal it's so	o continue with Til		
		14:11 3TAD	and reevaluate Th	a situation		
11:15		There Dog	ed Tin Greens This	e this making the		
		The skip	Dan which & ask	and Fre de storedon		
		He has me	oan which I ask	Isa spoke to him		
		This much	in and everyThing	Summer To be ander		
		webses	not received The	SKIR WAL YET.		
12:00		Tim called.	and said he was be	in held Up. They		
		may have	Topmp off nator	- before the con		
		more uki	for TO OUT local	W.		
2:00		Down To 13	36.57.	<u> </u>		
		bit green	x/ax on run#15	136.5-146.51		
3:30	ļ .	Drillers ST	arted to set well	and after the two		
	<del> </del>	10 47 52	reens were lon	er into have then		
7.5	<del> </del>	grapped	Tland, Non Fis	him of severs		
4:00		SVCASSEU!	ly fished out sex	eers, we are non		
-	-	setting &				
	<del> -</del>	1	1/2 To 1201 - 3 6.	<del>₹</del>		
	<del>                                     </del>	9 500	atizens used	<del></del>		
	5:30	finish	Tagged at 23: -	They raw out a f titter son		
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Technical Oversig	ght Signature (	) 01	_	Date		
L		Ja Hoon	nes	4/13/00		
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Project $A/N$	1 DNA	PL FYDD				
Driller	Calana		Drilling Subcontractor	Drilling Subcontractor		
Well Number Technical Oversight  MRS 3 4 J. Noo skester			A F.I Oversight Firm			
MRS	34	J. NoowkesTen	WSKC			
Location M-Ba			Date 4/14/08	Page3 of		
Start 8: 30	Stop	Oversight on 1	Description of Activities/Remarks			
		nesterda, nes	ecation well and inches well and and 92'  and 92'  and 91.2'  a pulcts - 82'  entonite pellets to	poured sand Filter		
		pack up To 97	: when we ran out	OF JANG.		
	<del>                                     </del>	Topof Filters	and-921	1.		
		Top of Fix sa	4-91.2	pas		
8:30		The state of the s	a full (1 = 8 t t	L de 70		
12:00		Completed ave 7	en parte persons	rypanie.		
		States				
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Technical Oversig	ht Signature (	Jan Hondy	Date	. /. /4		
		pro thouse		4/14/00		